2017

# Hera Stove

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# HERASTOVE

Matthew Kleinman + Søren Sibbesen

# HERASTOVE

800 million people worldwide are chronically malnourished while 1 billion lack access to clean and safe water. This problem largely stems from poverty and lack of financial stability disproportionately affecting women and children who spend much of their time providing for their families, themselves, and their communities.

Analysts say eliminating disease and death due to unclean water and poor sanitation would reap billions of dollars in health and productivity gains. Estimates show for every dollar spent, there would be an economic return between $3-$34, depending upon the country.

We have created an affordable humanitarian utility that can simultaneously cook food and purify water, and even create additional fuel from residual biomass to empower and encourage independence for people in sub-Saharan Africa.

To address the challenges related to water, we must work in a spirit of urgent cooperation, open to new ideas and innovation, and prepared to share the solutions that we all need for a sustainable future.

*Ban-Ki Moon, UN Secretary General*

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## 02

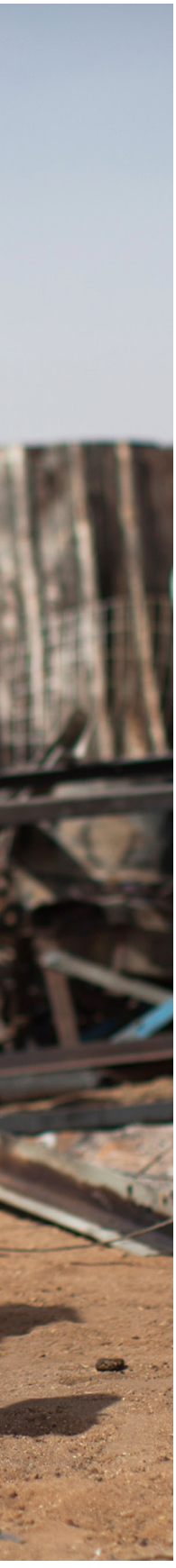


## 03



## 06

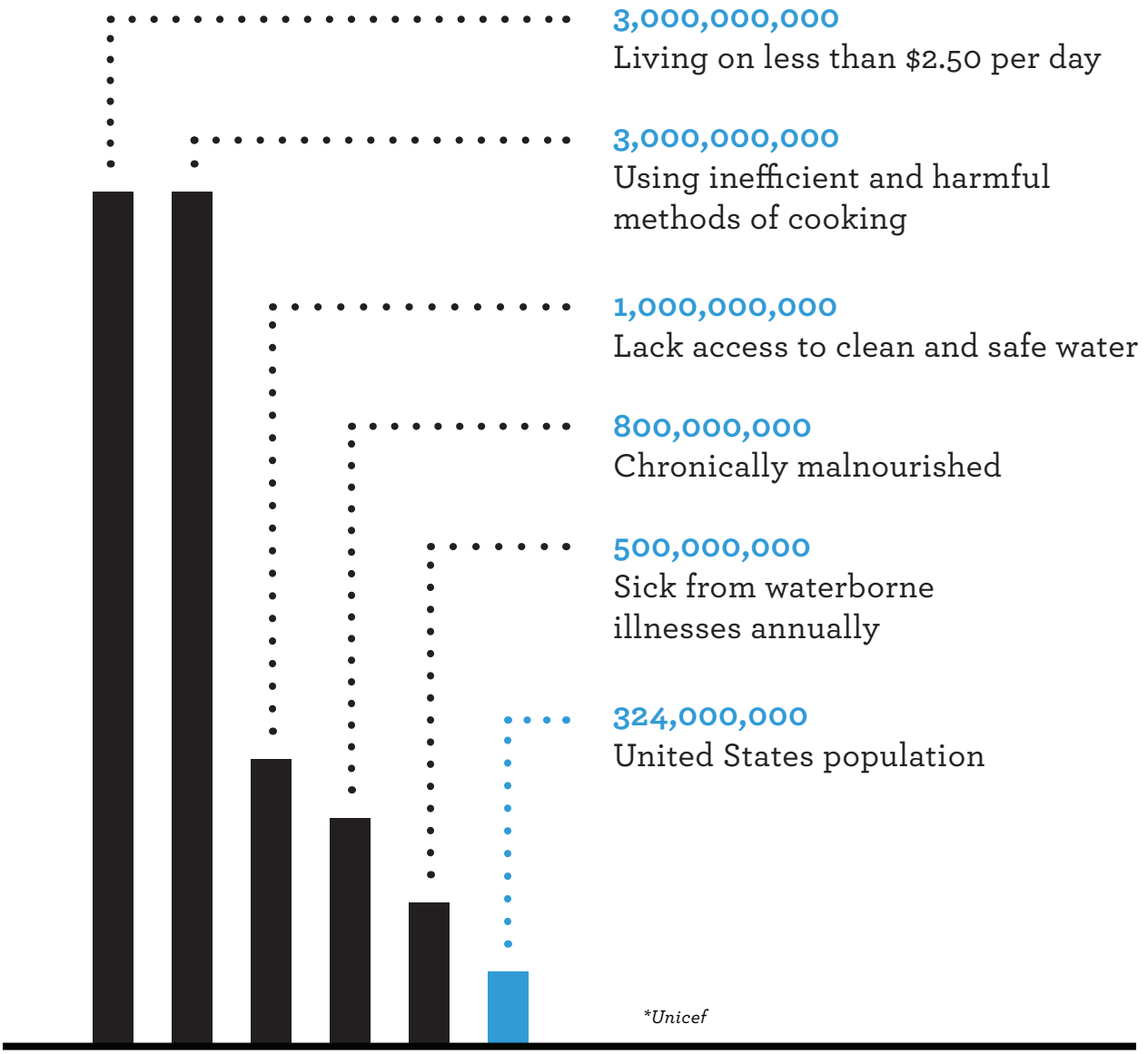
*Photo: Albert Gonzalez Farran*



# 01

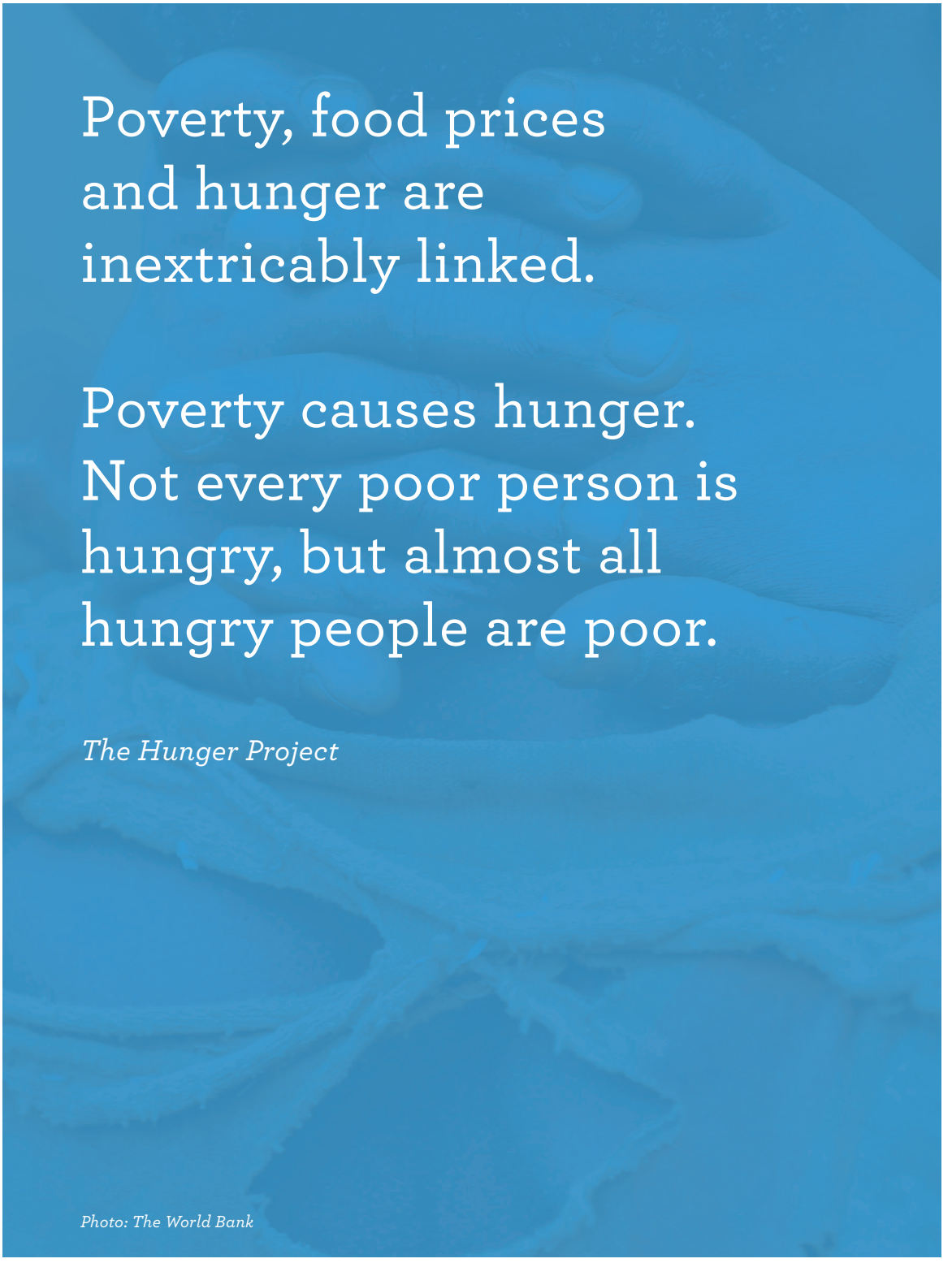
## Defining the Field

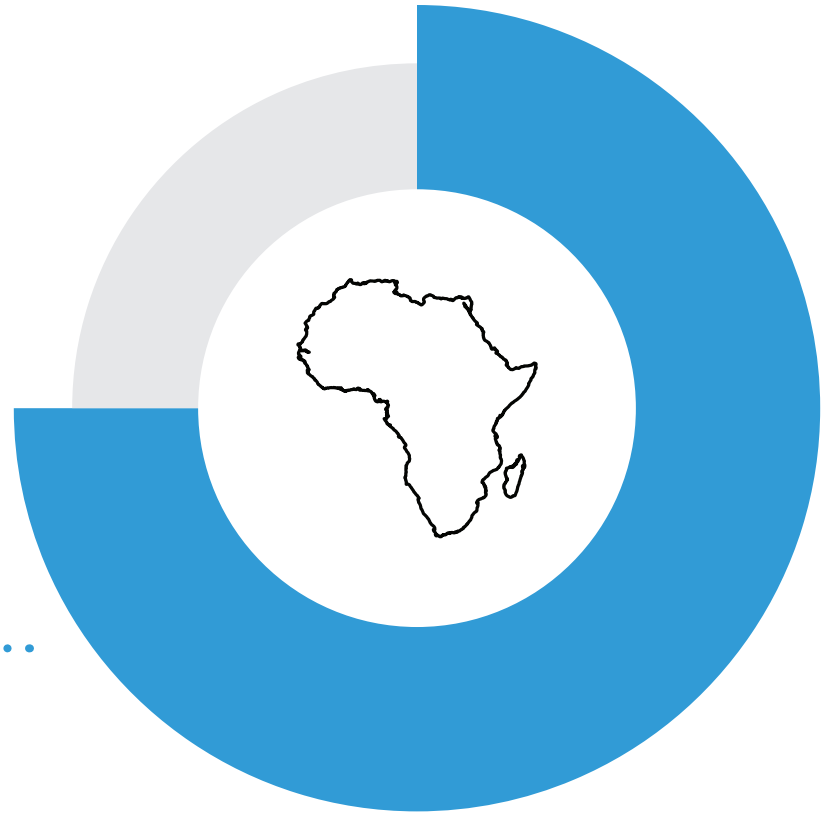
# Hard Facts


3,000,000,000
Living on less than $2.50 per day
3,000,000,000
Using inefficient and harmful methods of cooking
1,000,000,000
Lack access to clean and safe water
800,000,000
Chronically malnourished
500,000,000
Sick from waterborne illnesses annually
324,000,000
United States population
*Unicef


**98%** of the world's undernourished people live in developing countries

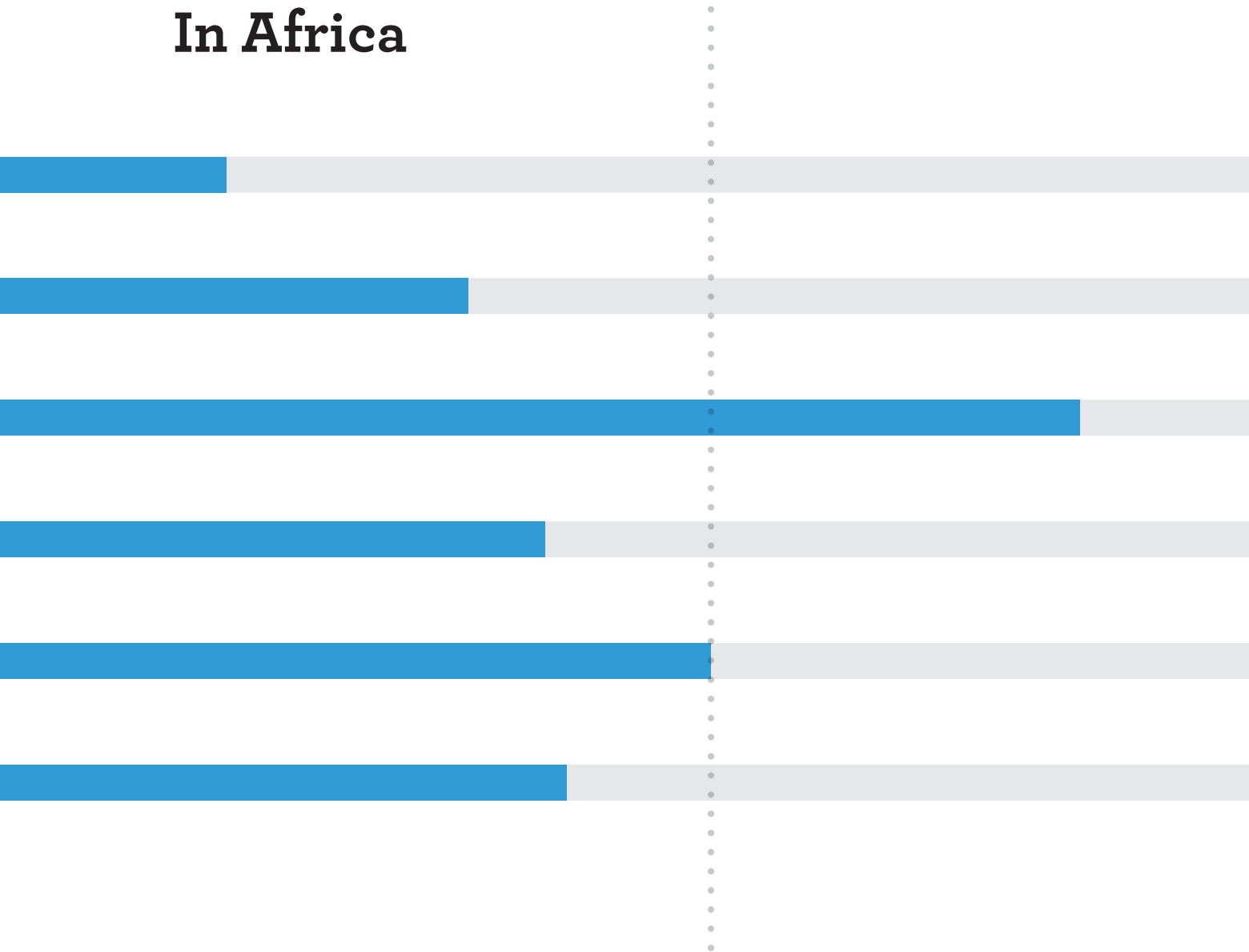
**Unicef*


Poverty, food prices and hunger are inextricably linked.
Poverty causes hunger. Not every poor person is hungry, but almost all hungry people are poor.
*The Hunger Project*
*Photo: The World Bank*



**75%** of poorest countries are in Africa, including Zimbabwe, Liberia and Ethiopia. In 2013, the ten countries with the highest proportion of residents living in extreme poverty were all in **sub-Saharan Africa** (The Borgen Project).

# In Africa



**16%** Have access to drinking water through a household connection. Even when water is available there are still risks of contamination.

**33%** Without access to any reliable drinking water sources. 102 million still dependent on surface water in sub-Saharan Africa.

**80%** Rely on biomass products such as wood, charcoal and dung in order to cook due to lack of access to electricity.

**37%** Of those who lack access to clean water globally, are living in sub-Saharan Africa.

**50%** Suffering from a water-related illness like cholera which thrives where crowded housing and water facilities are suboptimal.

**38%** Of the world's refugees are located in Africa. 11 million people, including stateless people and returnees, exist in Africa.

**The Water Project, UNHCR*

*Photo: Olivia Grey Pritchard*

Clean water isn't just a matter of life and death. It's not just about thirst, hunger and sanitation. It's about **opportunity.** Without clean water, the world's poorest people stay poor.

*Water for Women*

**25%** Of women's time in rural Africa, or roughly 40 billion hours annually, is spent walking long distances to collect water; resulting in missed school, work and playtime because bringing water home is one of the main responsibilities for women and girls (Water for Women).

# Women's Roles

### Household Fuel and Water Provisioning

Throughout Africa women and girls are the main providers of household water supply and sanitation, and also have the primary responsibility for maintaining a clean home environment. The lack of access to safe water and sanitation facilities therefore affects women and girls most acutely (World Bank).

### Care and Domestic Work

Tasks such as housework, cooking, care for children, the sick, and elderly household members, are necessary to maintain families. Women and girls bear a large portion of these unpaid reproductive responsibilities which are often made more time consuming due to the lack of adequate household technologies. Cooking and childcare are among the most time-consuming of women's reproductive responsibilities (World Bank).

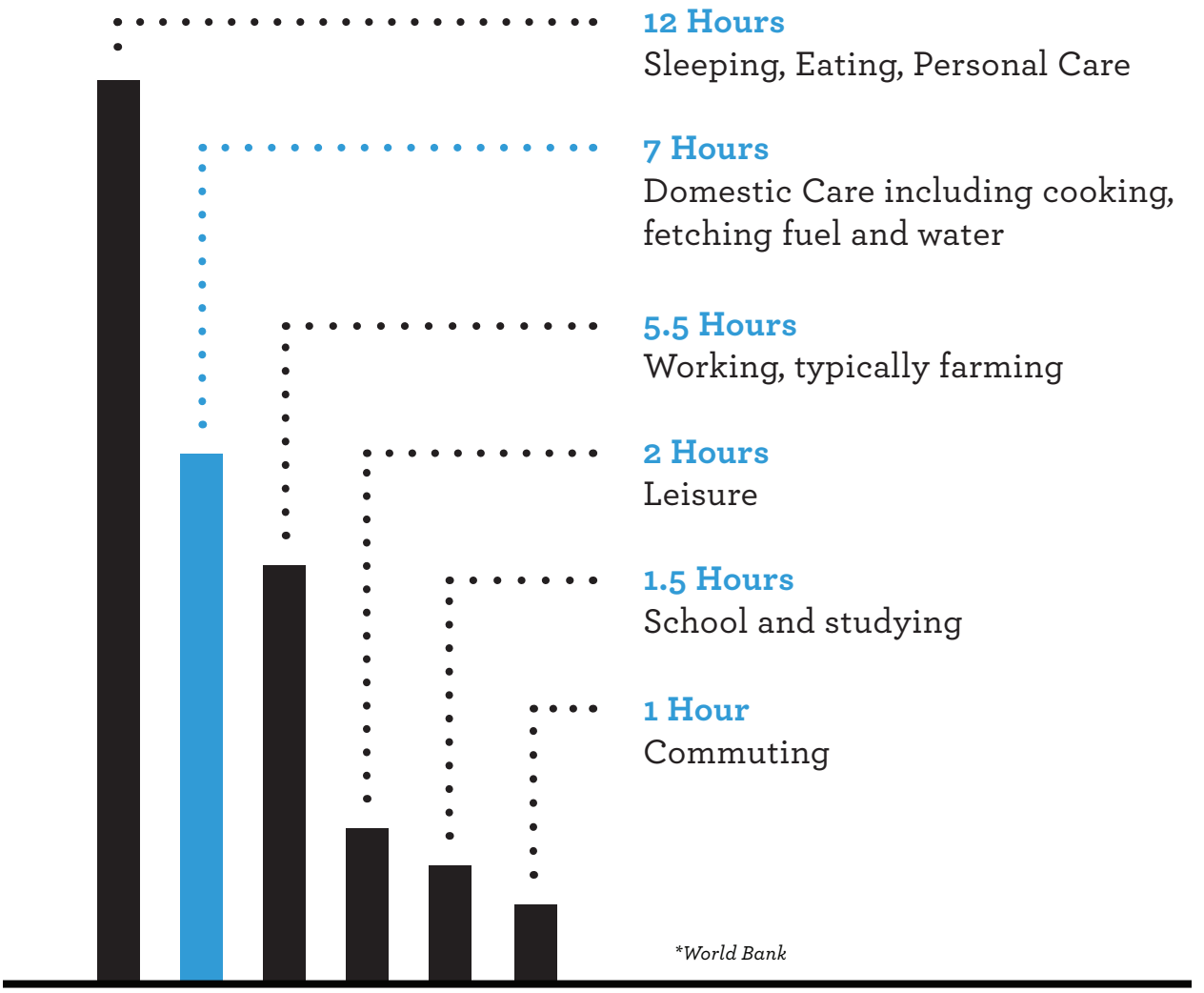
### Agriculture

Agriculture is the main source of livelihood in Sub-Saharan Africa. It accounts for 35% of the region's GDP and 70% of its employment. Women provide about 50-75% of all agricultural labor in the region (FAO).

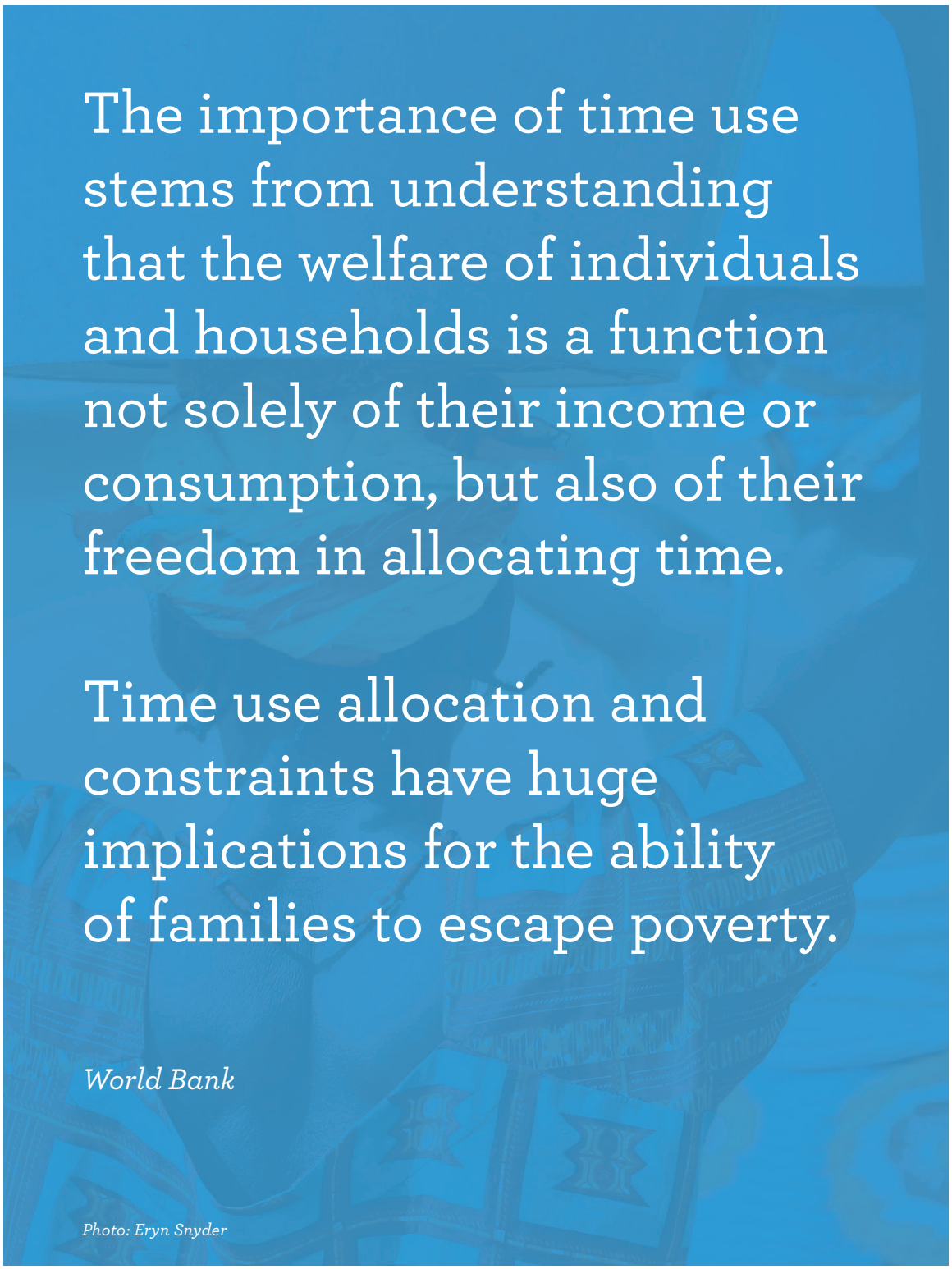
# The world's most precious resource - **Time.**

*Hanneke Willenborg, Vice-President Unilever*

*Photo: Mozambique Renewables*




In all regions, women spend at least twice as much time as men on unpaid domestic work. Women who are employed spend an inordinate amount of time on the double burden of paid work and family responsibilities; when unpaid work is taken into account, women's total work hours are longer than men's in all regions (World Bank).



The importance of time use stems from understanding that the welfare of individuals and households is a function not solely of their income or consumption, but also of their freedom in allocating time.

Time use allocation and constraints have huge implications for the ability of families to escape poverty.

*World Bank*

*Photo: Eryn Snyder*


Photo: Getty Images

# 02

# Key Insights

# "The Ripple Effect"

Time lost due to walking and waiting for resources is having a ripple effect on women's lives, their communities and whole economies.

**Only 16% of people in sub-Saharan Africa had access to drinking water through a household connection.** However even when water is available in small towns, there are risks of contamination due to several factors.

Additionally, an estimated **80% of the entire continent's population uses fuelwood for cooking and heating.**

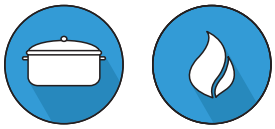
## ACCESS TO RESOURCES ARE THE PROBLEM

Women with minimal access to resources have limited choices that too often means low-wage labor.

In Africa, 90% of work gathering water and wood, for the household and food preparation, is done by women; Time NOT spent on income generating activities, caring for family, or attending school.

WHIC

CH IMPACTS TIME AND THEREFORE INCOME



In some regions, women spend up to 5 hours a day collecting fuel wood and water and up to 4 hours preparing food.

Women reinvest up to 90% of their income back into their families, improving their family's health and nutrition and ensuring that their children go to school.

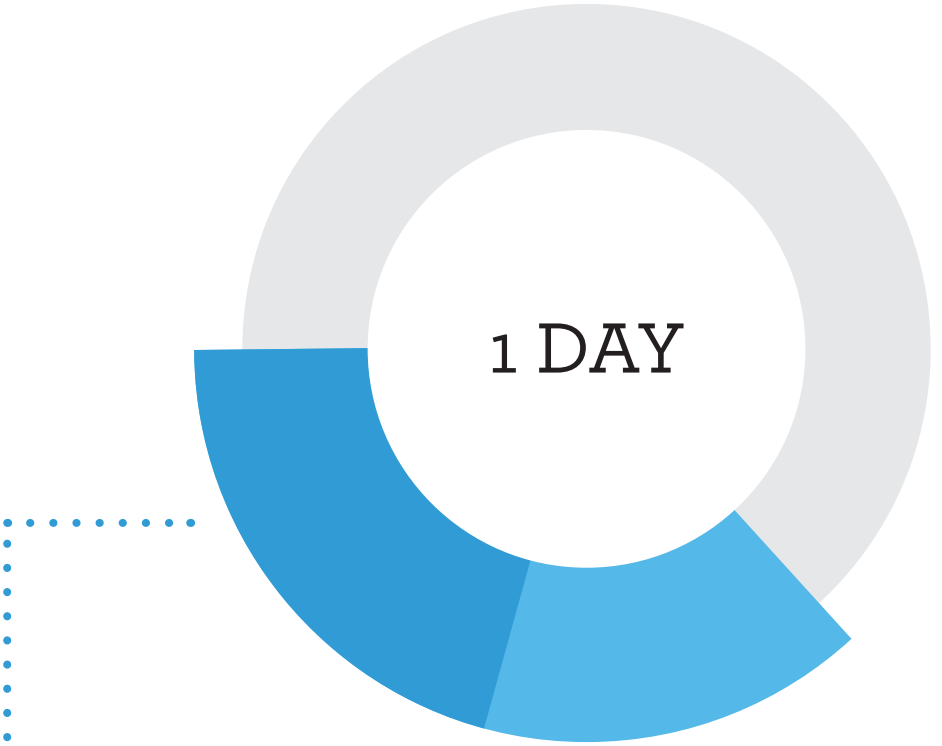
For every $1 USD spent on water and sanitation there is a $4 USD economic return.

Women represent 40% of the global labour force, yet in sub-Saharan Africa 40 billion working hours are lost every year to water collection.

RESULTING IN A LOSS OF OPPORTUNITY

**Water for Women*

# Extracting an Opportunity




## Cooking plus fuel and water collection account for five to nine hours of woman's day


Photo: MMDOC


Photo: Joe Lasky


Photo: Practical Action

Women, as primary caregivers in the home, are responsible for **collecting water, finding fuel wood** and **cooking on sub-par stoves,** which, above all, accounts for most of the time taken away from a chance to pursue other personal opportunities like an education or income generating activities.

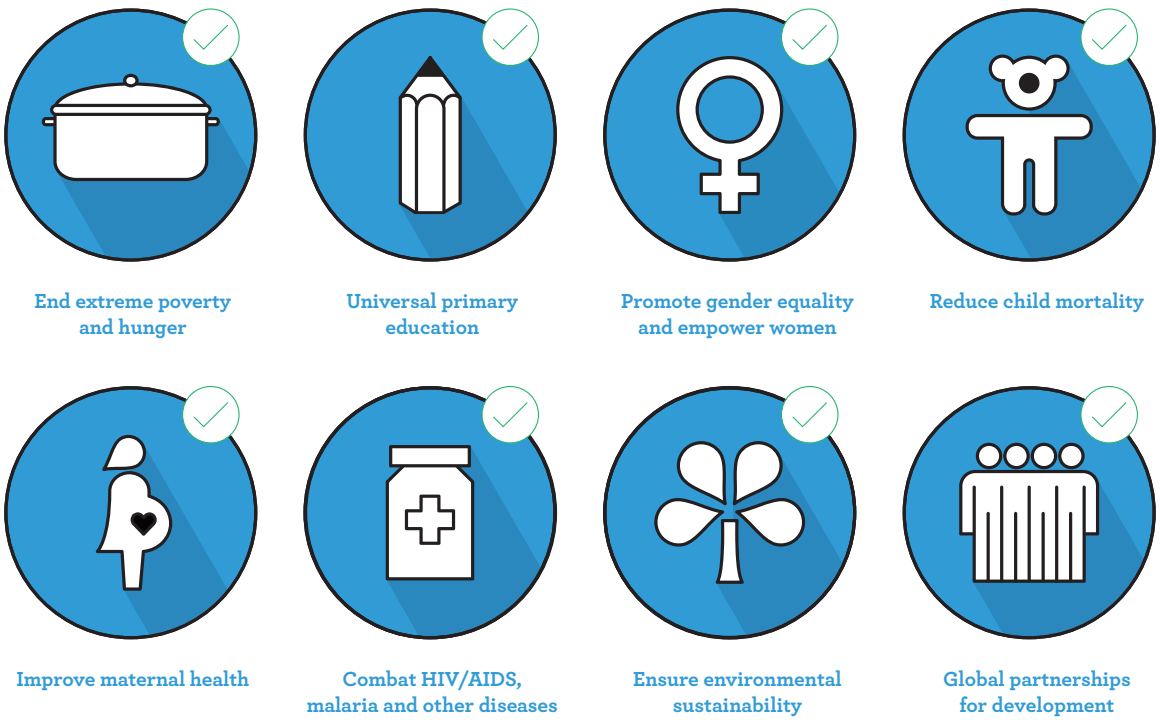
Traditional stoves leads to incomplete combustion of fossil fuels, causing high carbon emissions due to **low combustion** efficiency, leading to **higher cooking times** and **inefficient use of fuelwood** (NC State).

> The need for **clean, safe water** and a **cookstove** go in hand-in-hand.

*Mike Oldani, Project Manager Impact Carbon*

*Photo: Adopt a Clean Cookstove*

# Millennium Development Goals




A clean cook stove is one intervention that addresses all the problems associated with inefficient use of solid fuels and a bridge towards the fulfillment of the Millennium Development Goals with regard to ending poverty and hunger, gender equity, child health, maternal health and environmental sustainability (ARSO).

Clean cook stoves means one less day of struggling to find enough wood to survive. It means increased safety, better health, sustainable fuel consumption, higher income, more time and increased employment (ARSO).

# Market Research

Numerous factors influence a family's decision to adopt a new cookstove or fuel including socioeconomic, behavioral, and environmental. While a range of benefits can be achieved through the adoption of clean cookstoves and fuels, experience in community development has shown that improved technologies or cleaner fuels do not guarantee usage. Households are reluctant to adopt technologies or fuels that are:

- **Difficult to install or maintain**
- **Less convenient**
- **Lacking cooking options**
- **Expensive**

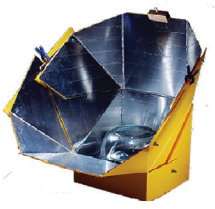
Despite these issues, there are steps to take to encourage adoption of clean cookstoves in Africa. A consumer financing program, for instance, that provides interest free micro-loans can enable families to invest and buy a clean cookstove more easily.

However, the key factor has to be that the alternative has to be satisfactory to the consumer and adapt to their lifestyle rather than the other way around (Global Alliance).



























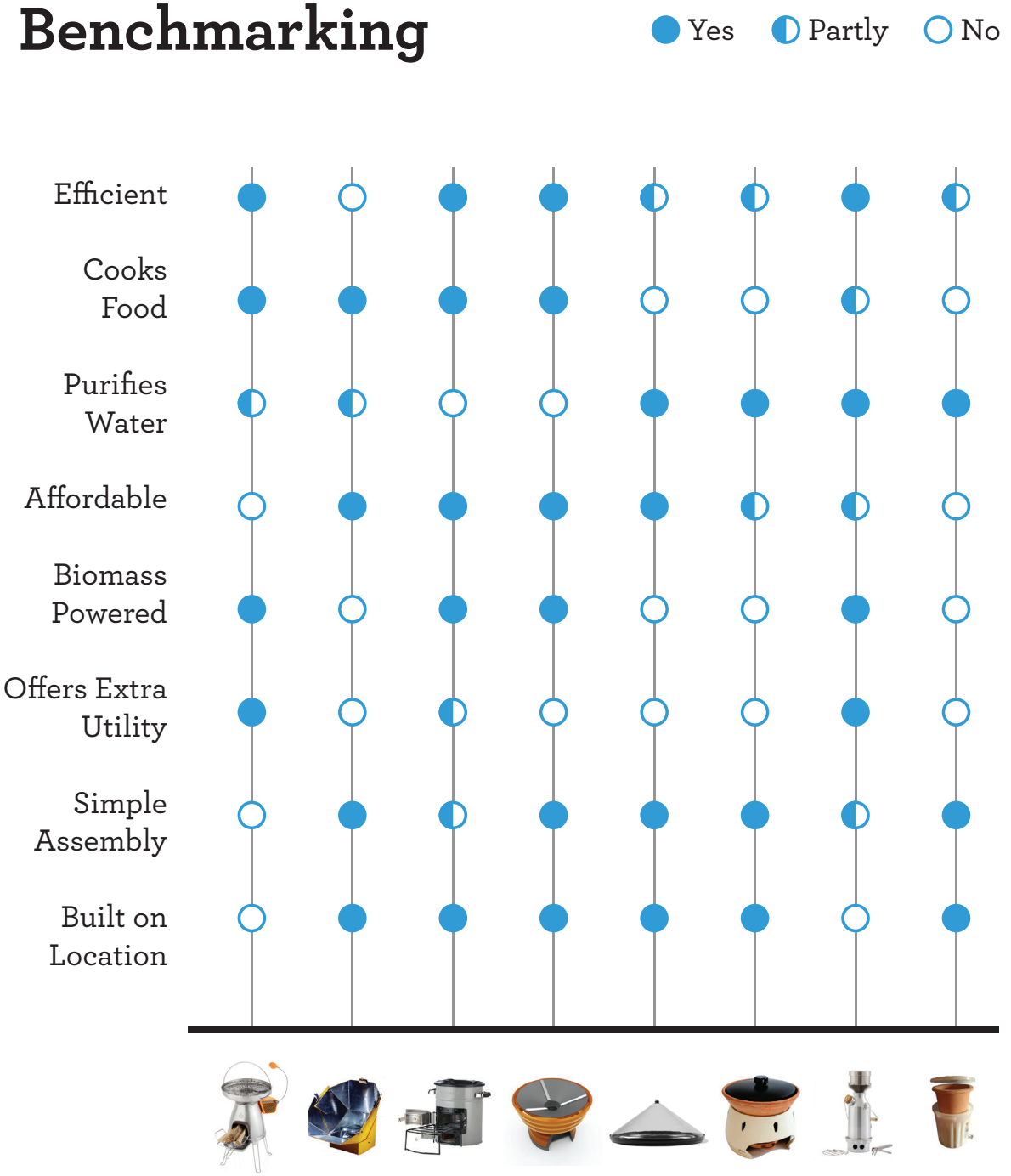








# Benchmarking




Our analysis of domestic care products that specifically address physiological needs already being offered in sub-Saharan Africa yielded two major categories – products that can cook food, and products that can purify water. While benefits and pitfalls ranged within both offerings, it was clear that the need for a cooking device and the need for a purification utility were in high demand.

Our research suggested however, that there were few products that can do both simultaneously, and for the products that are capable, they are largely dependent on other external devices.

# Fuels Research

**Wood -** Accounts for 90% of energy for cooking, heating, and other uses in sub-Saharan Africa.

**Briquette -** Processed biomass material of different sizes and shapes made from agricultural waste and recycled materials.

**Crop Residue -** Straws, stems, stalks, leaves, husks, shells, peels; non-edible plant parts left in the field after harvest.

**Charcoal -** Energy-dense charred wood, with no moisture, light-weight, easy-to-handle, and convenient fuel.

**Electricity -** Efficient, but requires connection to the country's grid system, which many lack access to.

**Solar -** Direct thermal energy can be used to power solar cook stoves, which can save time, work, money, and fuel.


**Ethanol -** Clean liquid biofuel that can be made from a variety of feedstocks including sugary materials such as sugar cane.

**Natural Gas -** Flammable gas, consisting largely of methane and other hydrocarbons, occurring naturally underground.

**Liquefied Petroleum Gas -** Clean-burning, efficient fuel made from a mixture of propane and butane.

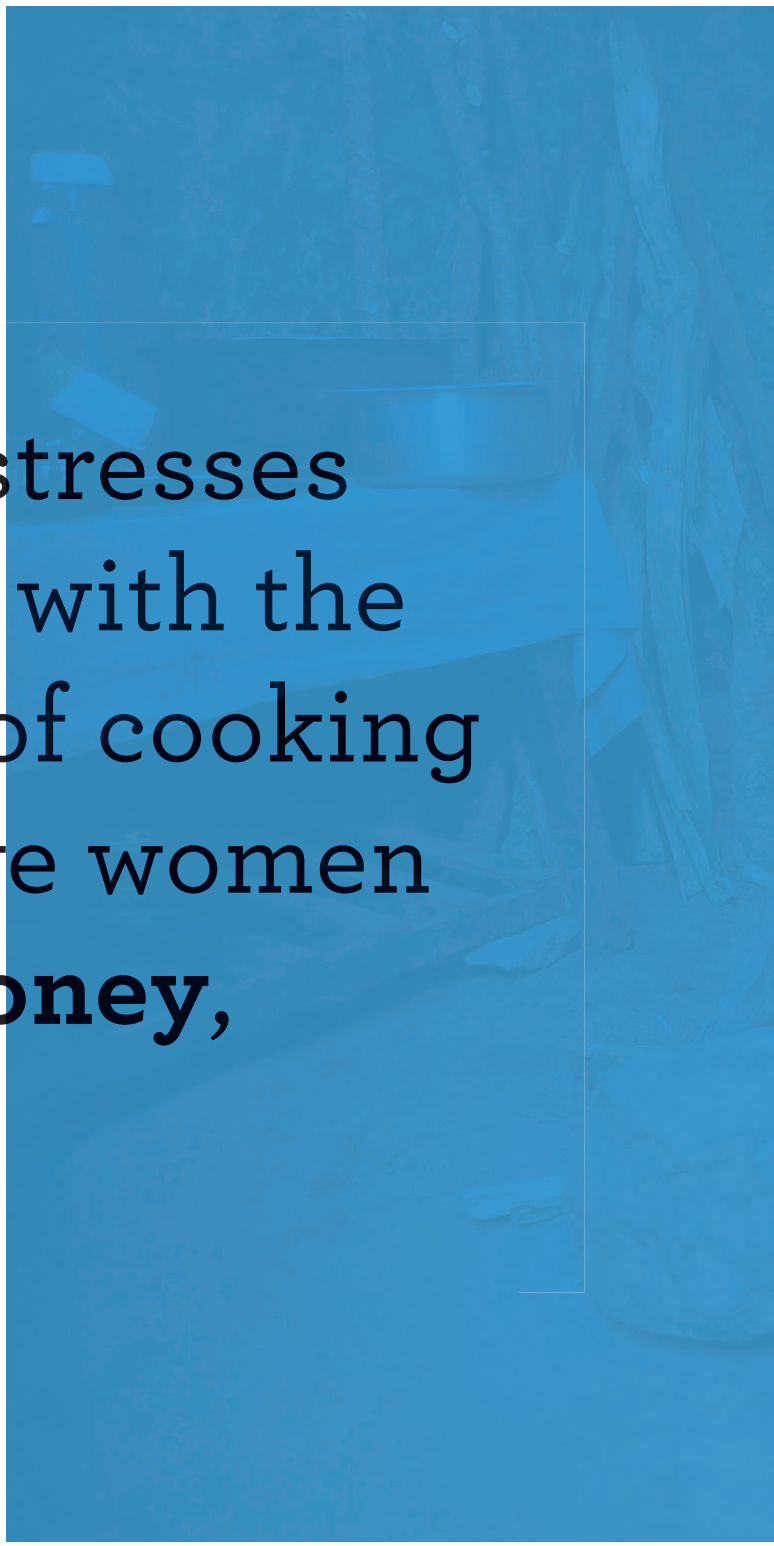
People like cooking with traditional fuels such as **wood and biomass,** others are just used to this method. Therefore when people get other stoves they will often not be used.

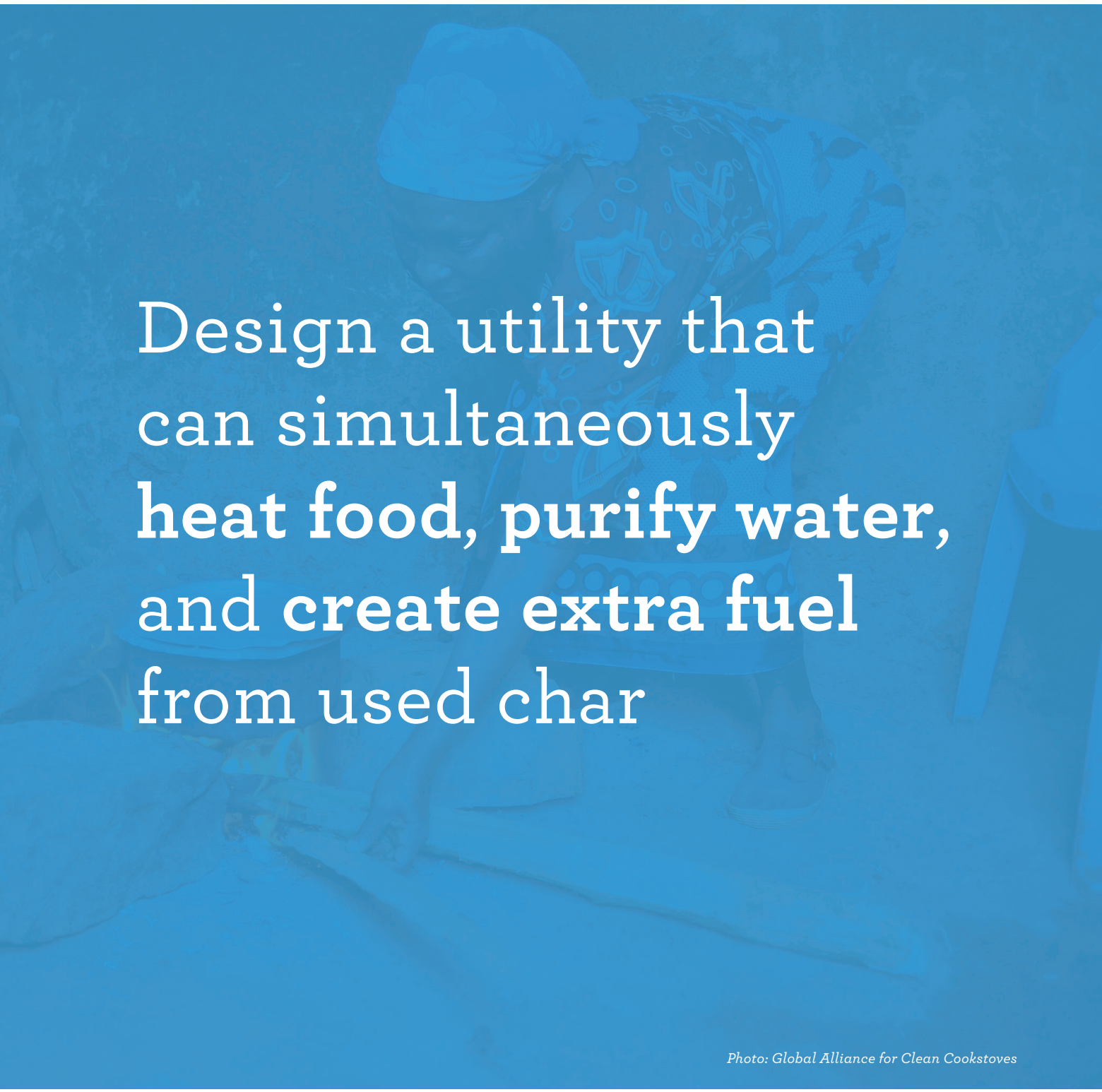
*Andrew Heath, Spokesman Practical Action*

*Photo: Practical Action*

## Brief

Minimize stresses associated with the daily task of cooking food to save women **energy**, **money**, and **time**





Design a utility that can simultaneously **heat food**, **purify water**, and **create extra fuel** from used char

*Photo: Global Alliance for Clean Cookstoves*


STANLEY

# 03

# Prototyping

# Built Models



*Mk. I Prototype*

Cooks Food

The design process began with building simple rocket stoves to help **understand their constraints and capabilities** before modeling advanced versions with improvements focused on the brief.

*Mk. II / Mk. III*


AIR FLOW AND COMBUSTION

Cooks Food


*Mk. IV / Mk. V*

**Cooks Food**

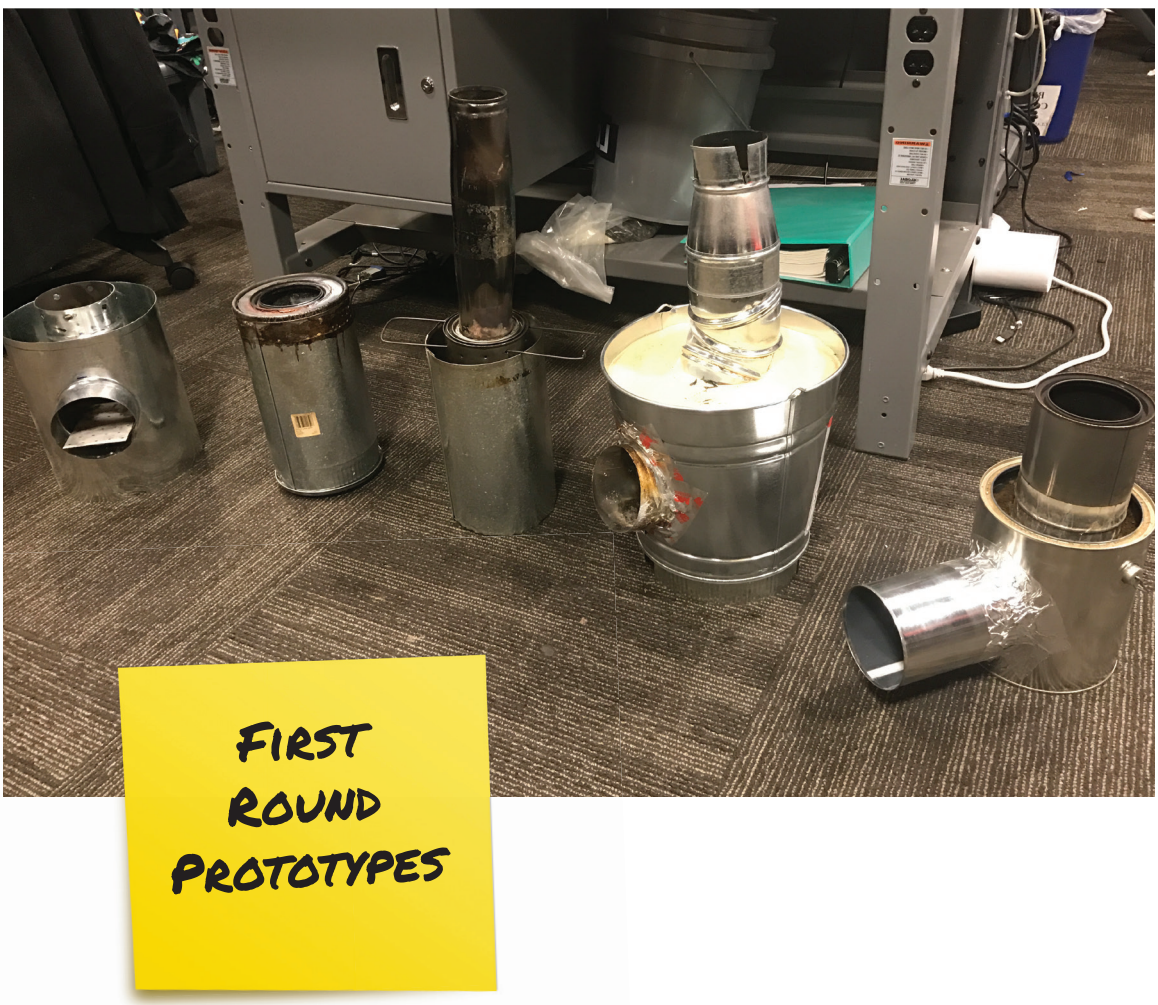
INCLUDED EXTERIOR VESSEL FOR WATER PURIFICATION

*Mk. VI*

IMPROVED CHAR COLLECTION

Cooks Food

First round prototypes had varying success ultimately proving **that heat from the flame had significant potential energy offering a variety of benefits.** We worked to design a gasification process to minimize harmful effects of pollution, a way to boil and purify water while simultaneously heating food, and a storage process for residual burnt char from a previous cook to be used again for fuel.



ADDED LID TO INSULATE BOILING WATER

*Mk. VII*

CHAR COLLECTION IMPROVEMENTS

Cooks Food

Creates Fuel

GASIFICATION STOVE. HIGHEST COMBUSTION YET!

*Mk. VIII*

Cooks Food

Creates Fuel

WATER INSULATES EXTERIOR UP TO 100°

FIRST MODEL TO BOIL WATER ~25 MIN.

*Mk. IX*

Cooks Food

Purifies Water

Creates Fuel

*Mk. X*


This prototype resembles **full proof-of-concept by both cooking food, simultaneously purifying water, and burning fuel at a high enough temperature to create activated biochar.**

Utilizing manipulated components already available on the market, the functional success of this model supported further develop of the form and components for manufacturing.

# 3D Models

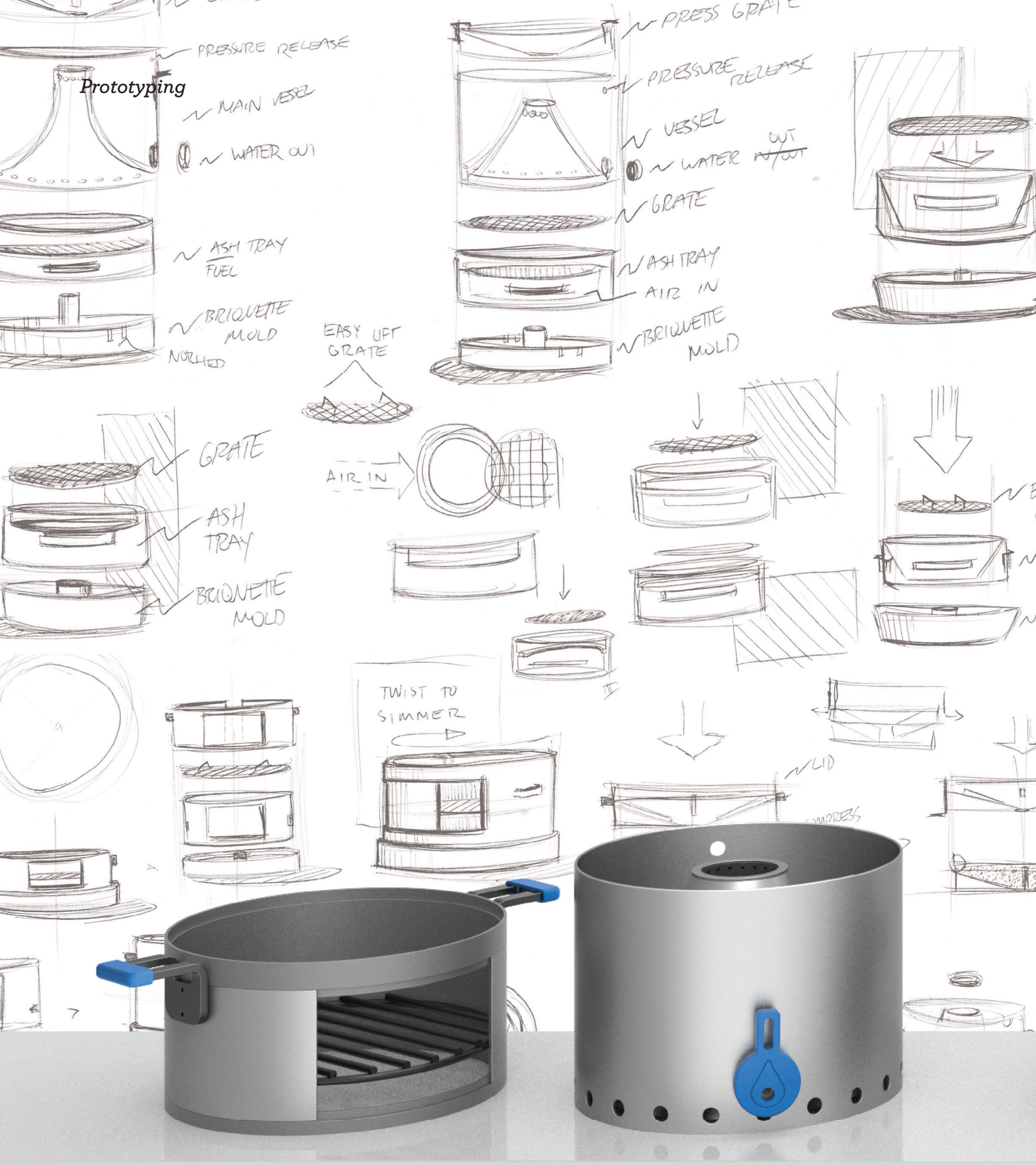

CHAR
COLLECTION
GRATE
SITS INSIDE
AIR INTAKE


WATER VESSEL
INNER CHIMNEY


DETACHABLE TOP VESSEL
AIR INTAKE
GRATE TOP?
REMOVABLE LID FOR CHAR
TOP LID INSULATES WATER?

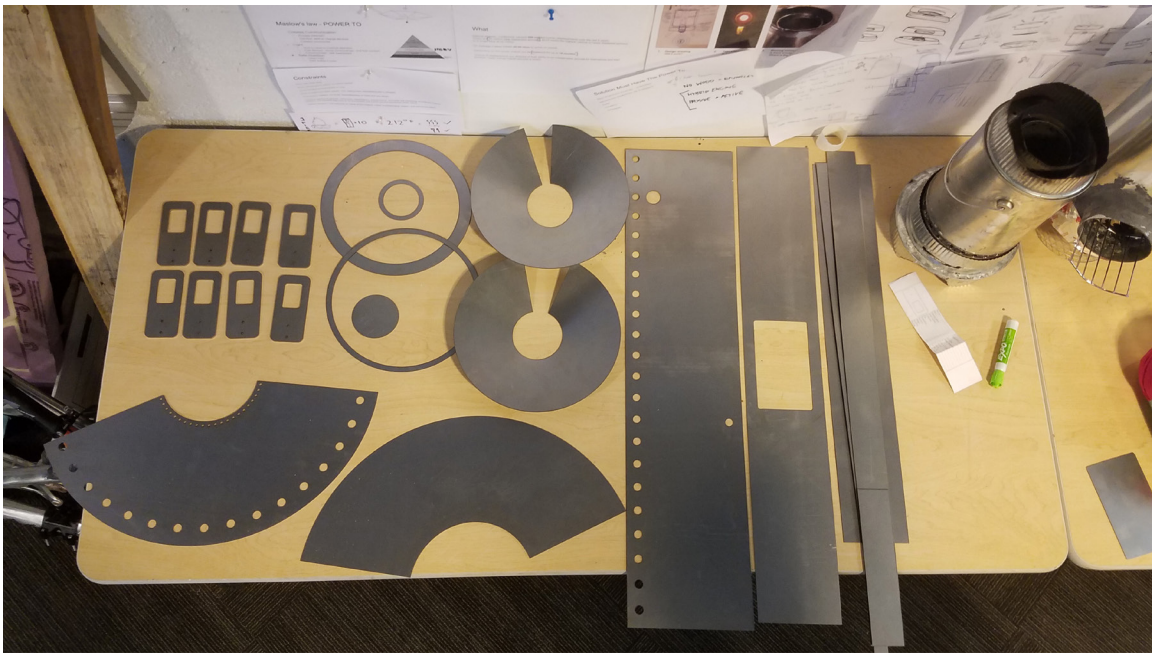
*Prototyping*

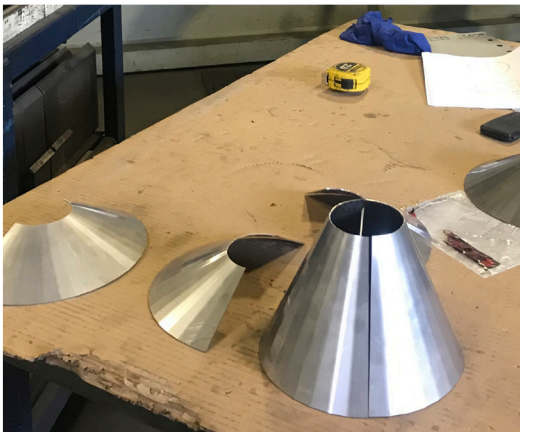

SIDE
FEED
TWIST TO SIMMER
TWIST TO SIMMER
MINIMIZE PARTS!!
BASE
TWIST TO
SIMMER

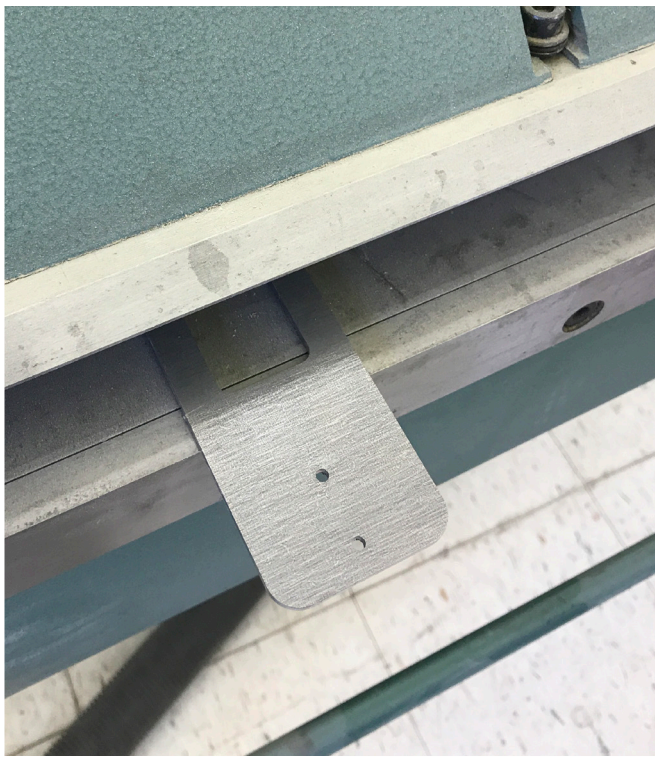

PRESSURE RELEASE
MAIN VESSEL
WATER OUT
ASH TRAY
FUEL
BRIQUETTE MOLD
PRESS GRATE
PRESSURE RELEASE
VESSEL
WATER OUT
GRATE
ASH TRAY
AIR IN
BRIQUETTE MOLD
EASY LIFT GRATE
GRATE
ASH TRAY
BRIQUETTE MOLD
AIR IN
TWIST TO SIMMER
LID


GRATE
TAPERED INTERIOR HOLDS GRATE
BRIQUETTE MOLD
ELEVATED BARS / EASY LIFTING
GRATE
STEEL CLIPS HOLD GRATE
ASH COLLECTION
BRIQUETTE MOLDING
TWIST TO SIMMER
EASY LIFT GRATE
ASH TRAY
BRIQUETTE MOLD
EASY LIFT
BASE / BRIQUETTE MOLD
COULD FIT LID FOR
CLIPS
FOOT PRESS
DRESS DOWN

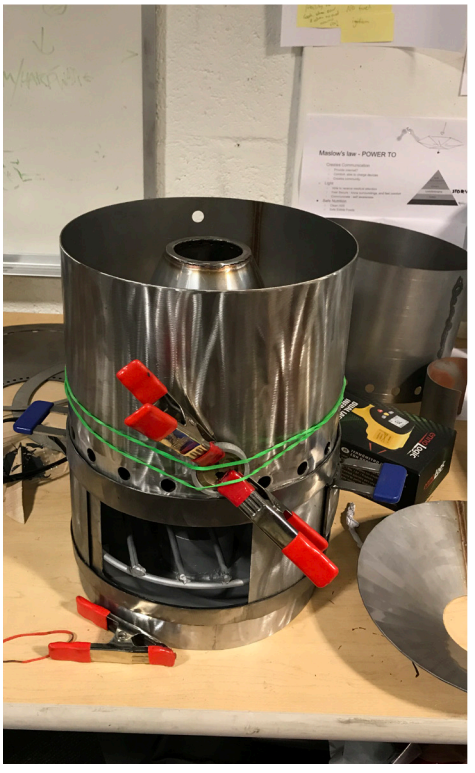
# Final Prototype

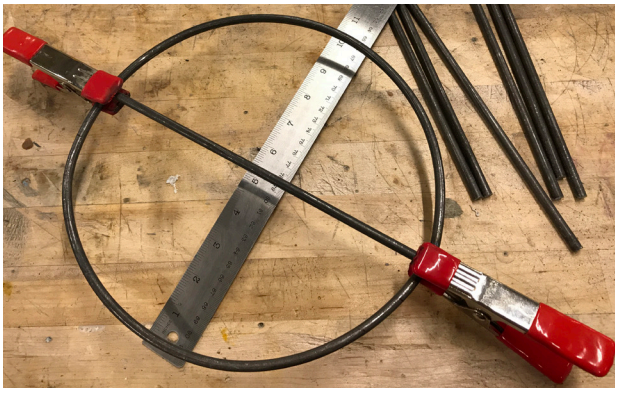




*Prototyping*



# 04

## Hera Stove

# 1. Disassemble

To begin using the stove, separate the components revealing the lid, water vessel, and wood chamber.

## 2. Fill Vessel

Using contaminated, unsafe water, fill the water vessel surrounding the chimney up to the pressure release hole. To prevent soaking the wood chamber, fill vessel while separated.

# 3. Fill Chamber

Using tinder and charcoal, wood, or a similar biomass, fill the chamber and ignite.

## 4. Reassemble

Once the fuel has been lit, seamlessly stack the water vessel on top of the chamber and place the lid on top of the vessel, insulating the water and creating a surface for pots and pans.

# Cook + Purify

Hera Stove saves time spent cooking by heating food while simultaneously purifying up to five liters of dirty water in the water vessel surrounding the hot chimney.

The lid of the stove is designed to allow the highest transfer of heat to all areas of the pot or pan cooking food evenly and efficiently. Additionally, airflow to the chamber can be adjusted by twisting the “simmer band” to increase or decrease flame size and temperature.

# 5. Clean Water

In roughly 25 minutes, Hera Stove can bring five liters of water to a rolling boil.  A hole on the back of the water vessel prevents pressure build up from the steam and will indicate when the water is boiling. Remove the lid and monitor the water to ensure it has reached a rolling boil for a minimum of just two minutes, enough to kill off all bacteria and contaminants.

## 6. Dispense

Once water has reached a rolling boil, turn the faucet to release the now safe water.  The design of the faucet forces the hand to turn away from the hot water, increasing safety.

# 7. Mold Briquette

Through a process of gasification, wood is converted into an activated carbon, or charcoal, offering a multitude of benefits.

**Fuel** | Hera Stove captures the charcoal in a mold and can be combined with residual biomass like leaves or dung and stamped with the lid, forming a briquette to later be used as fuel.

# Benefits of Charcoal

**Purification** | Carbon filtering removes contaminants using chemical adsorption trapping pollutant molecules in the carbon substrate.

**Income** | Charcoal use is high in African nations and people are making money as charcoal producers and resellers, while entrepreneurs are making products specifically designed to utilize it.

# How it Works

### 1. Primary Air Intake
Air flows through an opening in the chamber and can be controlled by twisting the simmer band to allow more or less

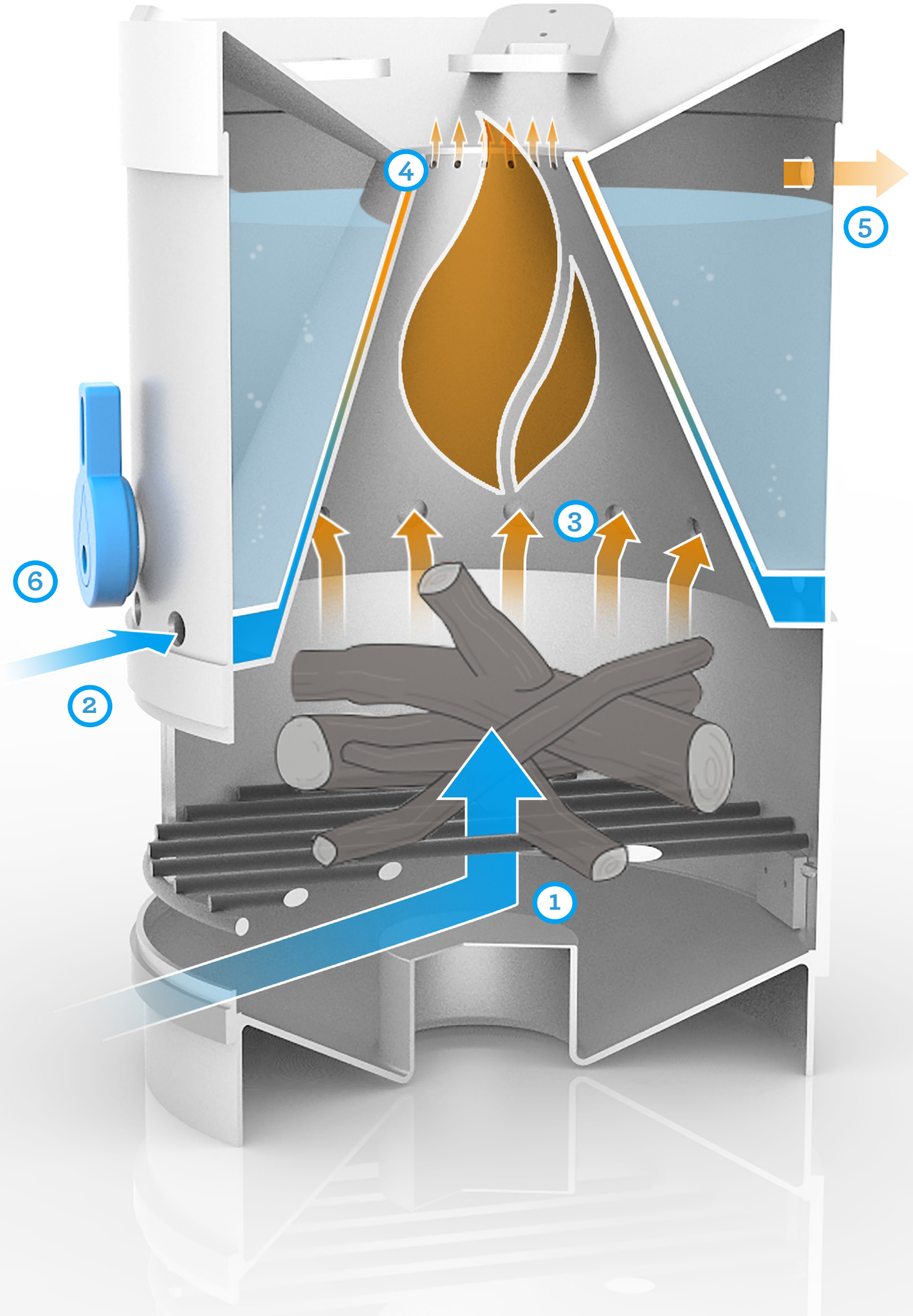
### 2. Secondary Air Intake
Holes on the exterior of the water vessel, around the bottom, allow air to flow up through the double walled chamber to be combined with gasses from the fire

### 3. Gas In
Holes around the interior of the chimney, around the bottom, allow gasses from the fire to flow into the double walled chamber to be combined with air

### 4. Gas Out
Holes around the interior of the chimney, around the top, allow a combination of gasses and air to flow back into the fire to be burned off resulting in a clean and efficient flame.

### 5. Pressure Release
A hole on the exterior of the water vessel allows prevents a build up of pressure from steam

### 6. Water Out
When water has reached a roiling boil for two minutes, turn the spigot to dispense


4
5
3
6
2
1

## Lid/Briquette Press

1. Pot Holders
2. Lid Band
3. Handles
4. Handle Covers

## Water/Chimney Housing

5. Cone Ring
6. Outer Chimney
7. Inner Chimney
8. Exterior Wall
9. Water Spigot

## Wood Chamber

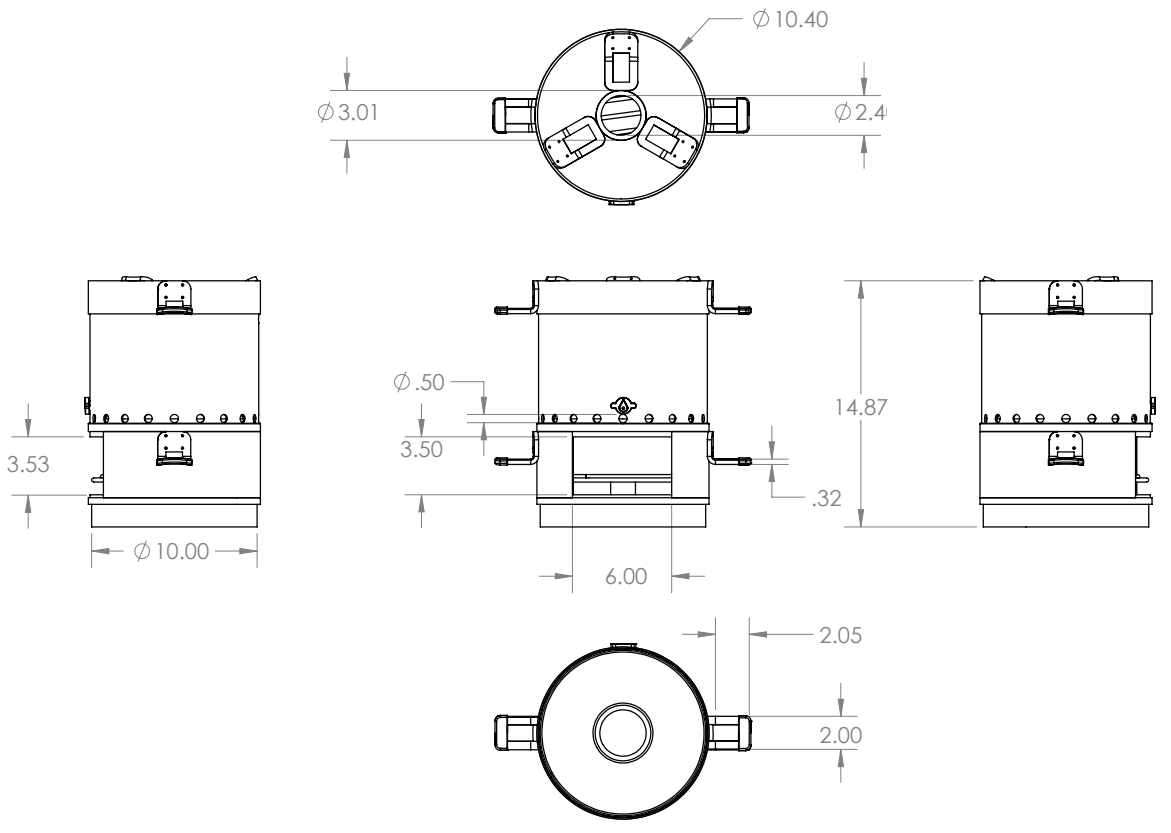
10. Support Band
11. Chamber Band
12. Simmer Band
13. Wood Grate
14. Grate Support
15. Support Band

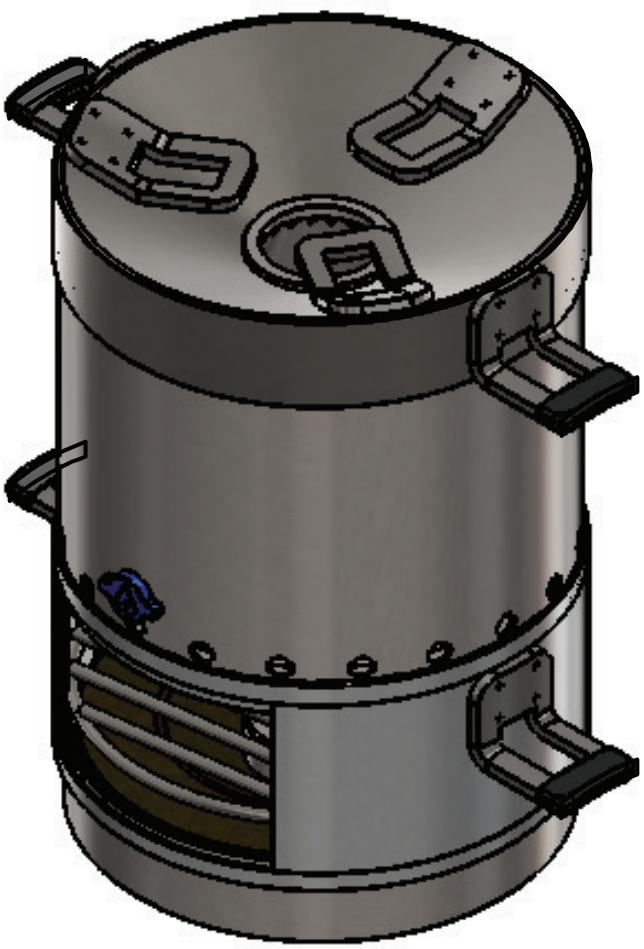
## Briquette Mold

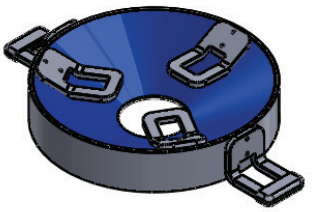
16. Briquette Mold

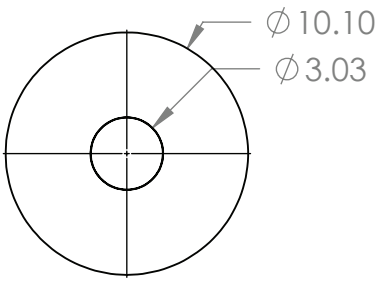

1
3
2
4
5
6
7
8
9
10
11
12
13
14
15
16

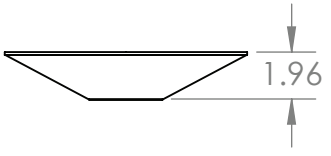
# Parts Drawings

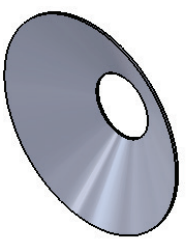




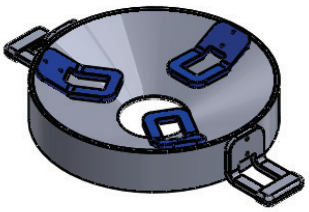


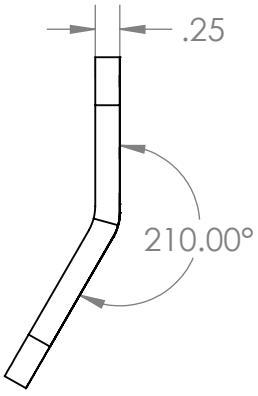


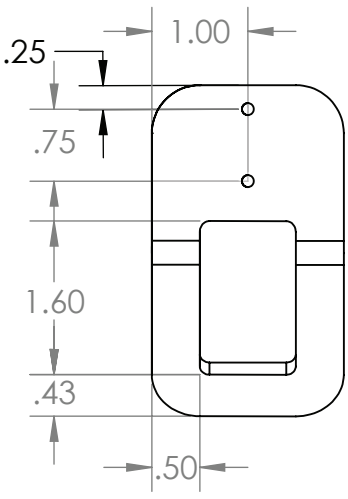



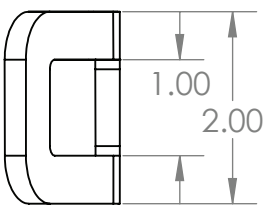



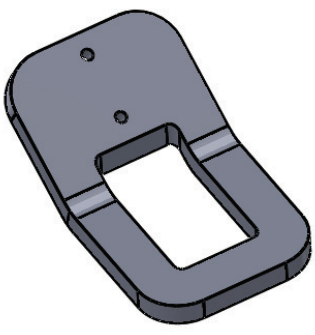
| | | |
|---|---|---|
| **TITLE:** Lid Dome | **USED ON:** Lid | |
| **SCALE:** 1:8 | **MATERIAL:** 20 Gauge Galvanized Steel | |
| **DATE:** 4/1/17 | **FINISH:** Painted | Dimensions in inches |



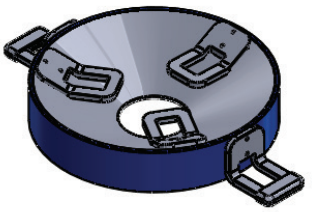


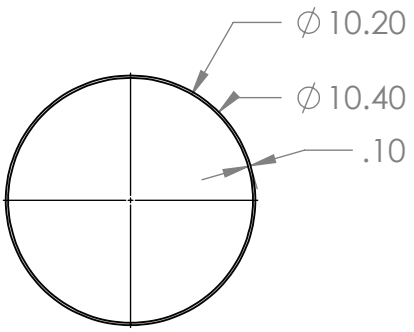



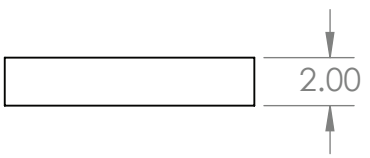



| | | |
|---|---|---|
| **TITLE:** Pot Holders | **USED ON:** Lid | |
| **SCALE:** 1:2 | **MATERIAL:** 14 Gauge Galvanized Steel | |
| **DATE:** 4/1/17 | **FINISH:** Painted | Dimensions in inches |



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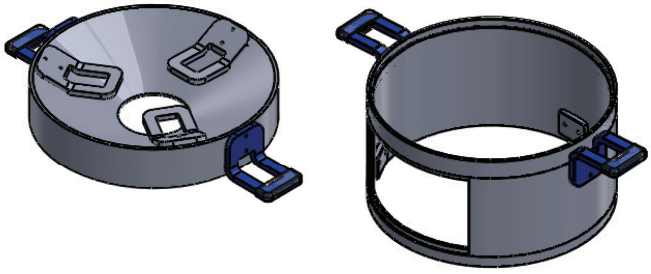
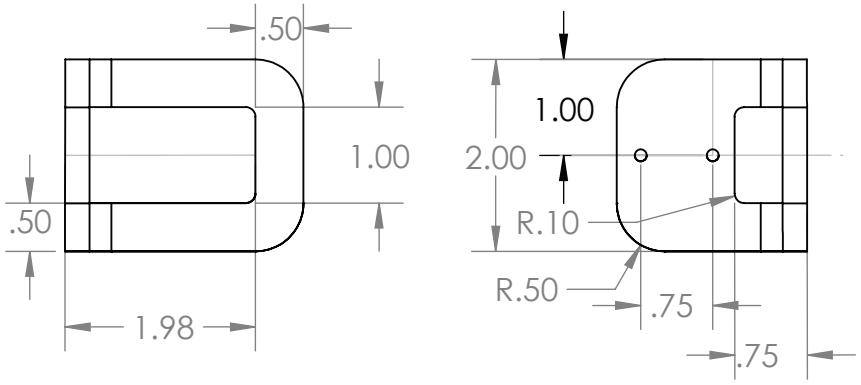
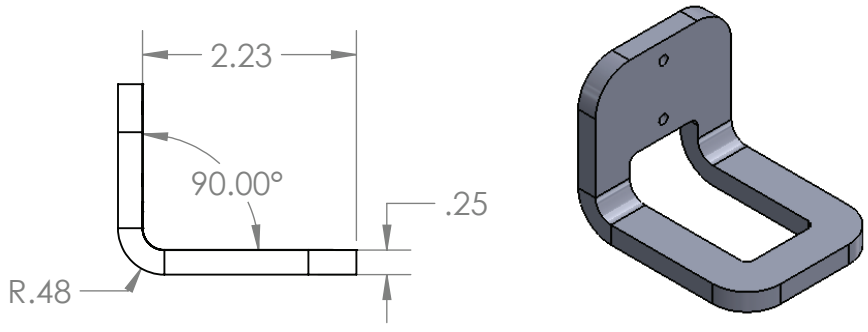
|---|---|---|
| **TITLE:** Lid Band | **USED ON:** Lid | |
| **SCALE:** 1:8 | **MATERIAL:** 20 Gauge Galvanized Steel | |
| **DATE:** 4/1/17 | **FINISH:** Painted | Dimensions in inches |



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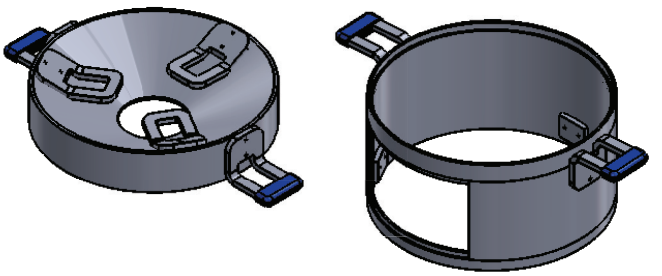
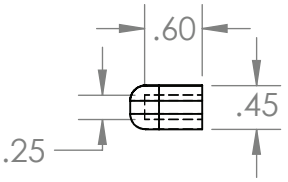
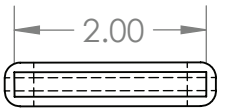
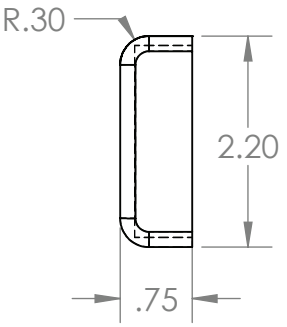
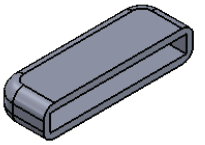
|---|---|---|
| **TITLE:** Handles | **USED ON:** Lid, Wood Chamber | |
| **SCALE:** 1:2 | **MATERIAL:** 14 Gauge Galvanized Steel | |
| **DATE:** 4/1/17 | **FINISH:** Painted | Dimensions in inches |



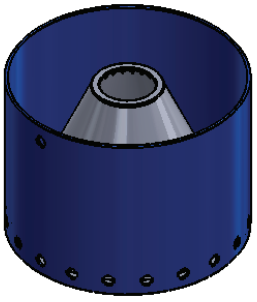


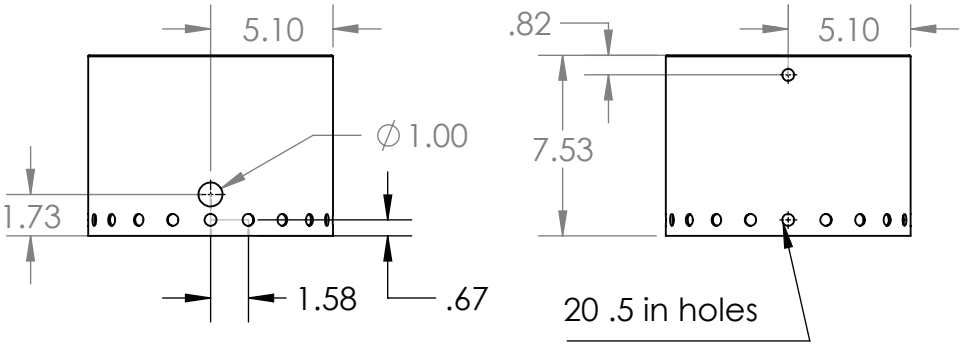



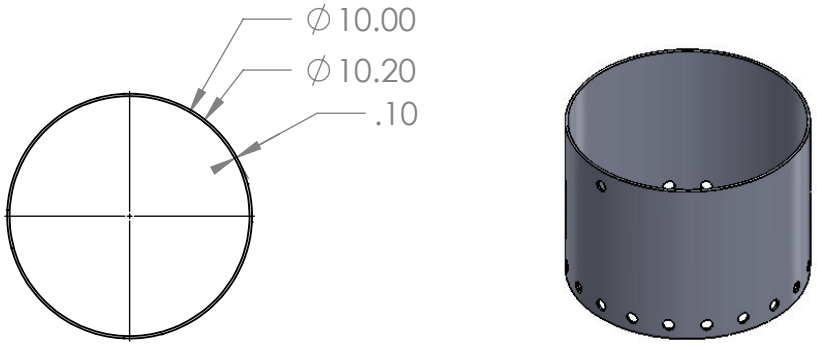



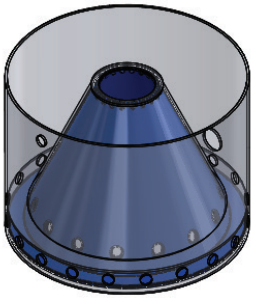
| | | |
|---|---|---|
| **TITLE:** Handle Covers | **USED ON:** Lid, Wood Chamber | |
| **SCALE:** 1:2 | **MATERIAL:** Silicone | |
| **DATE:** 4/1/17 | **FINISH:** Painted | Dimensions in inches |

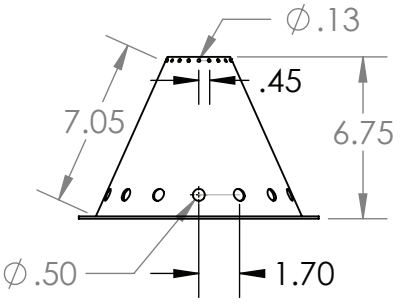


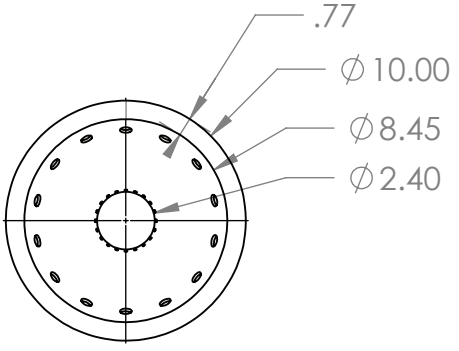


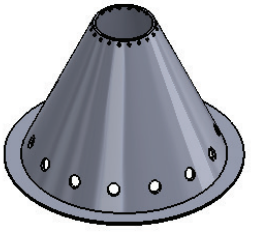




| | | |
|---|---|---|
| **TITLE:** Exterior Wall | **USED ON:** Water Vessel | |
| **SCALE:** 1:8 | **MATERIAL:** 16 Gauge Galvanized Steel | |
| **DATE:** 4/1/17 | **FINISH:** Painted | Dimensions in inches |





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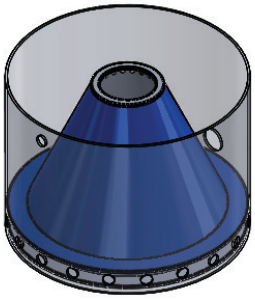
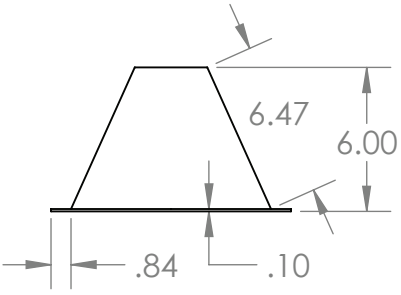
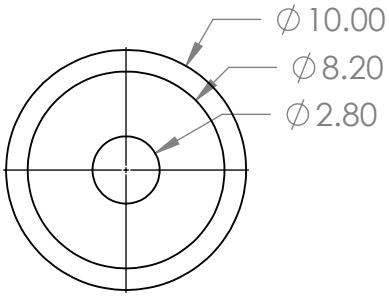
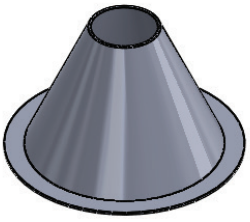
|---|---|---|
| **TITLE:** Inner Chimney | **USED ON:** Water Vessel | |
| **SCALE:** 1:8 | **MATERIAL:** 16 Gauge Galvanized Steel | |
| **DATE:** 4/1/17 | **FINISH:** Raw Unpainted | Dimensions in inches |






scale 1:8



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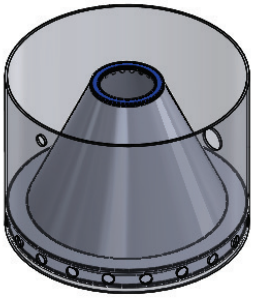
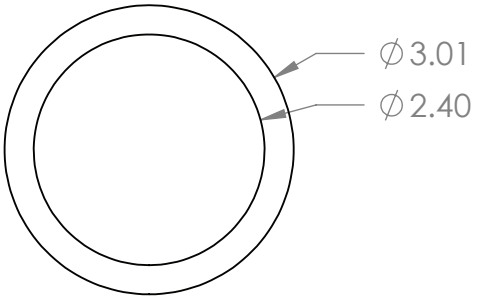
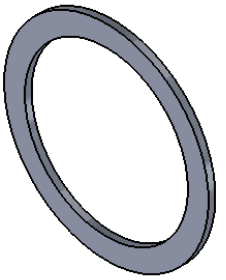
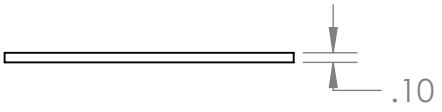
|---|---|---|
| **TITLE:** Outer Chimney | **USED ON:** Water Vessel | |
| **SCALE:** 1:8 | **MATERIAL:** 16 Gauge Galvanized Steel | |
| **DATE:** 4/1/17 | **FINISH:** Raw Unpainted | Dimensions in inches |

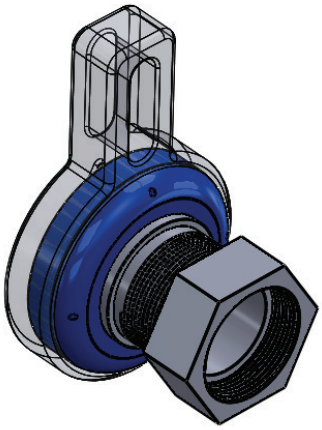




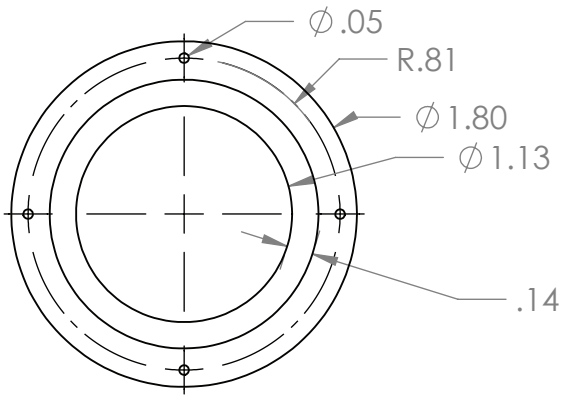



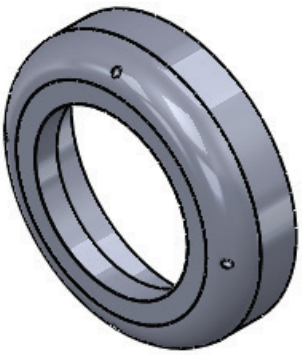


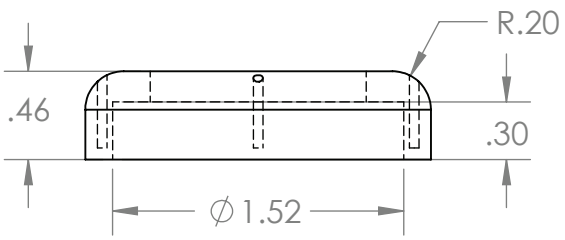

| | | |
|---|---|---|
| **TITLE:** Chimney Ring | **USED ON:** Water Vessel | |
| **SCALE:** 1:2 | **MATERIAL:** 20 Gauge Galvanized Steel | |
| **DATE:** 4/1/17 | **FINISH:** Raw Unpainted | Dimensions in inches |



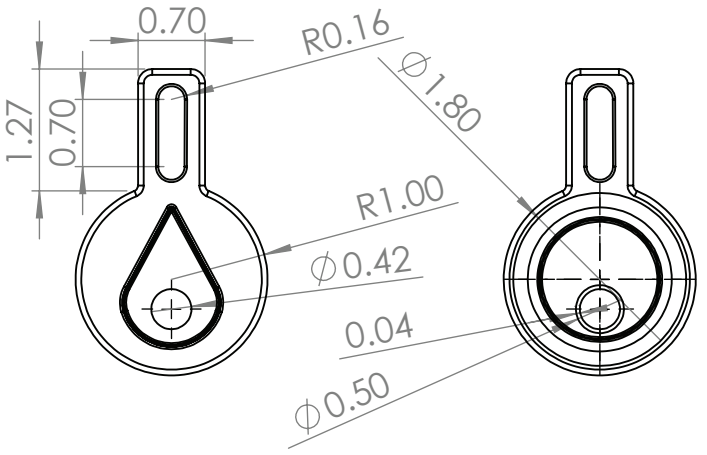
scale 1:1

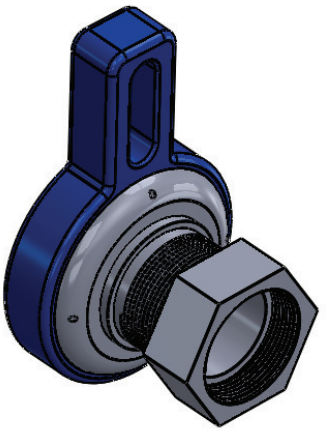


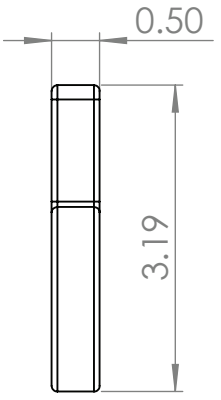



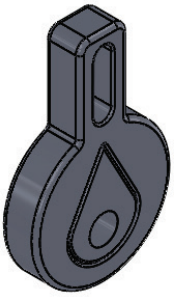



| | | |
|---|---|---|
| **TITLE:** Spigot Ring | **USED ON:** Water Spigot | |
| **SCALE:** 1:1 | **MATERIAL:** Silicone | |
| **DATE:** 4/1/17 | **FINISH:** Raw Unpainted | Dimensions in inches |

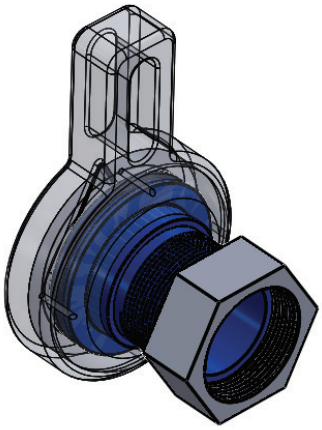


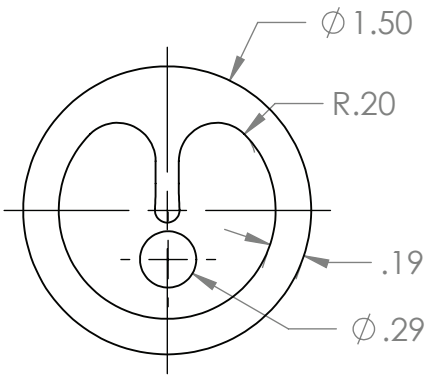



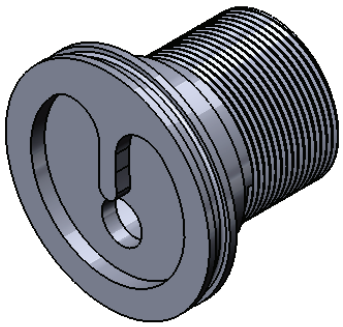


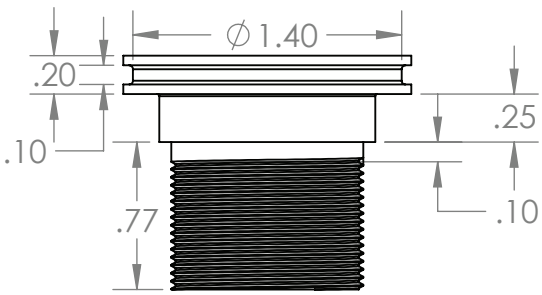



| | | |
|---|---|---|
| **TITLE:** Spigot Knob | **USED ON:** Water Spigot | |
| **SCALE:** 1:2 | **MATERIAL:** Silicone | |
| **DATE:** 4/1/17 | **FINISH:** Painted | Dimensions in inches |

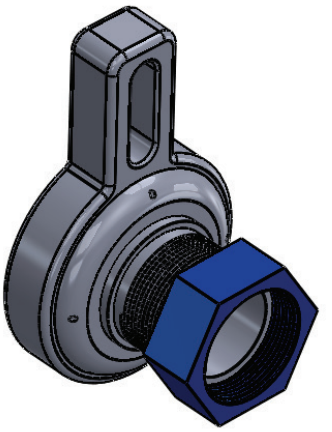


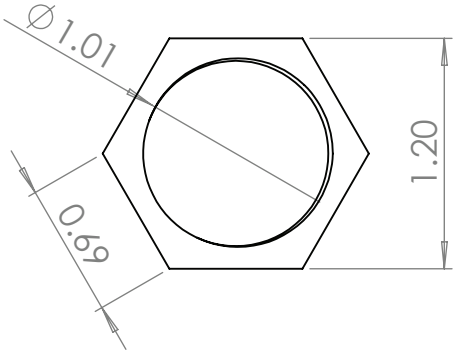


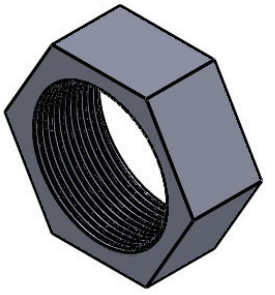



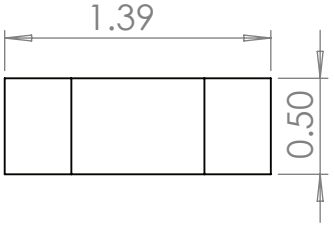



| | | |
|---|---|---|
| **TITLE:** Faucet | **USED ON:** Water Spigot | |
| **SCALE:** 1:1 | **MATERIAL:** Nylon | |
| **DATE:** 4/1/17 | **FINISH:** Raw Unpainted | Dimensions in inches |

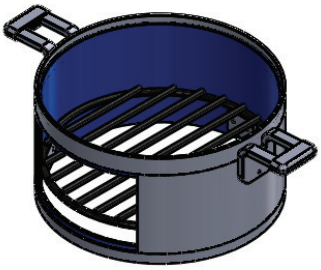


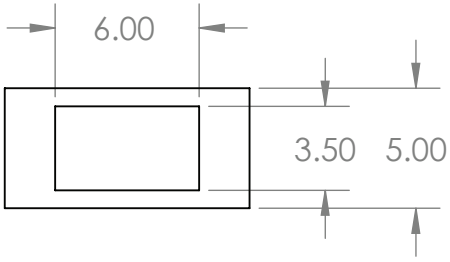


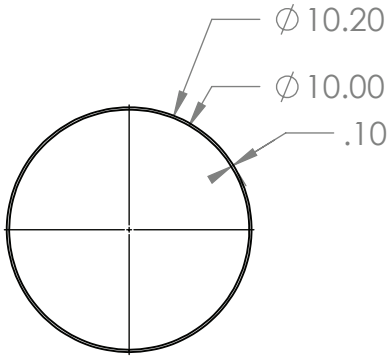



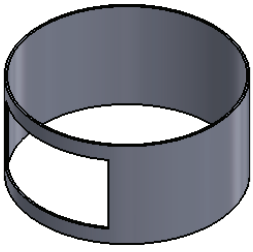



| | | |
|---|---|---|
| **TITLE:** Spigot Screw | **USED ON:** Water Spigot | |
| **SCALE:** 1:1 | **MATERIAL:** Nylon | |
| **DATE:** 4/1/17 | **FINISH:** Raw Unpainted | Dimensions in inches |

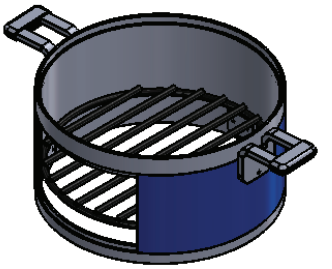


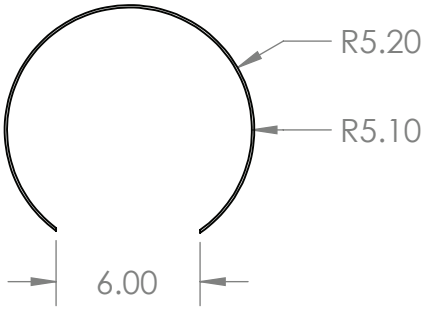


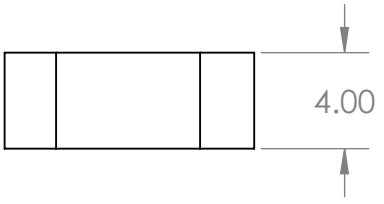



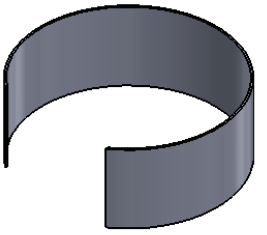



| | | |
|---|---|---|
| **TITLE:** Chamber Band | **USED ON:** Wood Chamber | |
| **SCALE:** 1:8 | **MATERIAL:** 20 Gauge Galvanized Steel | |
| **DATE:** 4/1/17 | **FINISH:** Raw Unpainted | Dimensions in inches |

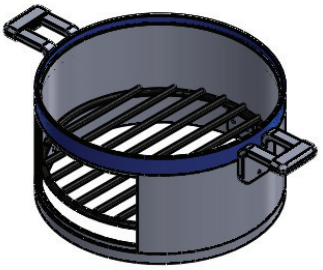


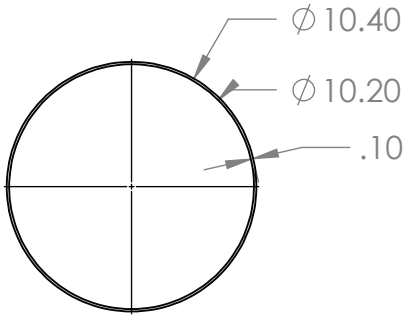


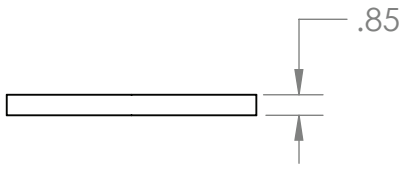



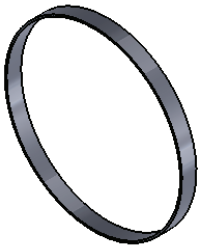



| | | |
|---|---|---|
| **TITLE:** Simmer Band | **USED ON:** Wood Chamber | |
| **SCALE:** 1:8 | **MATERIAL:** 20 Gauge Galvanized Steel | |
| **DATE:** 4/1/17 | **FINISH:** Painted | Dimensions in inches |

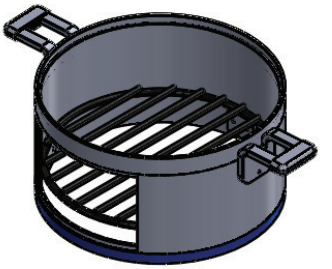


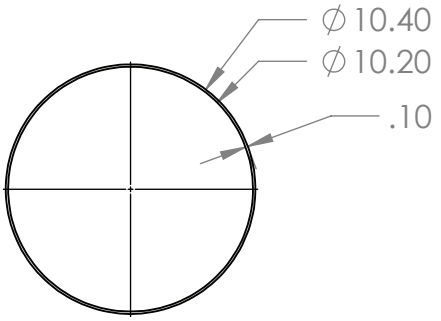


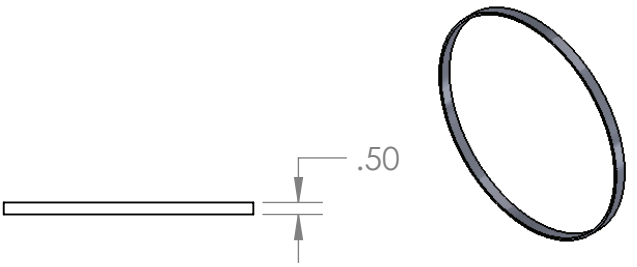



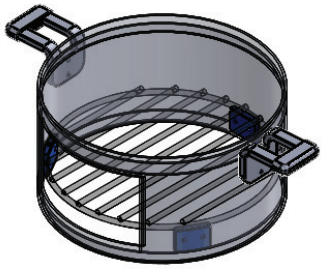
| | | |
|---|---|---|
| **TITLE:** Support Band I | **USED ON:** Wood Chamber | |
| **SCALE:** 1:8 | **MATERIAL:** 20 Gauge Galvanized Steel | |
| **DATE:** 4/1/17 | **FINISH:** Raw Unpainted | Dimensions in inches |

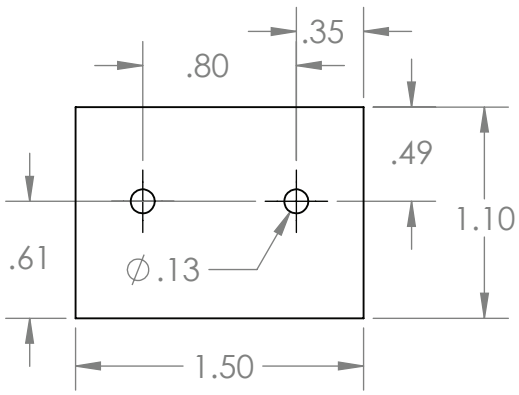


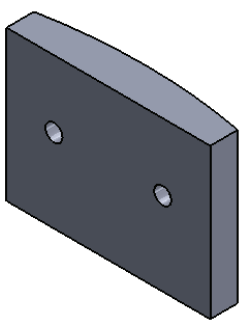


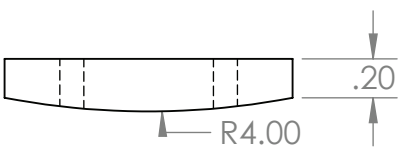




| | | |
|---|---|---|
| **TITLE:** Support Band II | **USED ON:** Wood Chamber | |
| **SCALE:** 1:8 | **MATERIAL:** 20 Gauge Galvanized Steel | |
| **DATE:** 4/1/17 | **FINISH:** Raw Unpainted | Dimensions in inches |

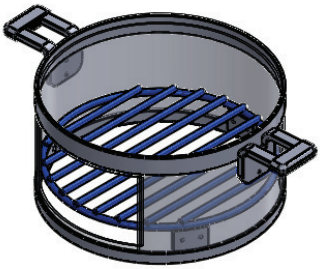


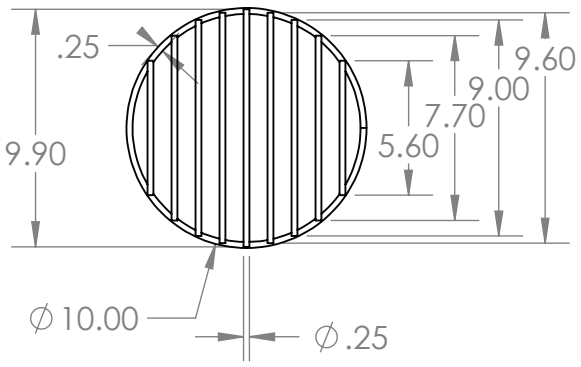


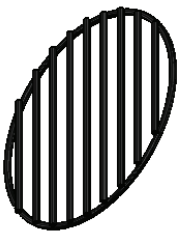





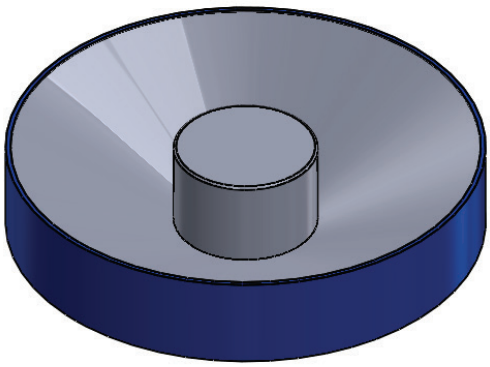

| | | |
|---|---|---|
| **TITLE:** Grate Support | **USED ON:** Wood Chamber | |
| **SCALE:** 1:1 | **MATERIAL:** 16 Gauge Galvanized Steel | |
| **DATE:** 4/1/17 | **FINISH:** Raw Unpainted | Dimensions in inches |

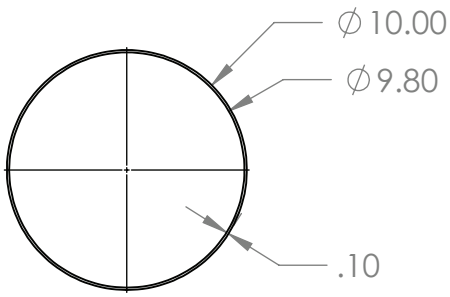


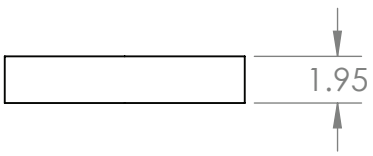


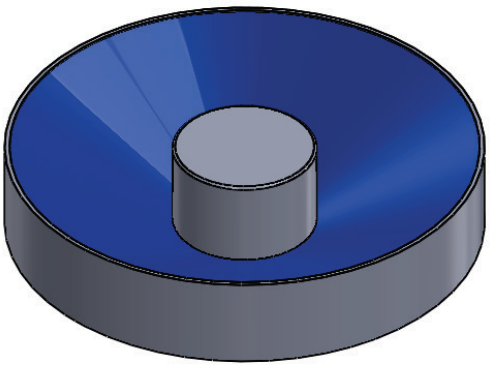

| | | |
|---|---|---|
| **TITLE:** Wood Grate | **USED ON:** Wood Chamber | |
| **SCALE:** 1:8 | **MATERIAL:** 1/4” Galvanized Steel | |
| **DATE:** 4/1/17 | **FINISH:** Raw Unpainted | Dimensions in inches |

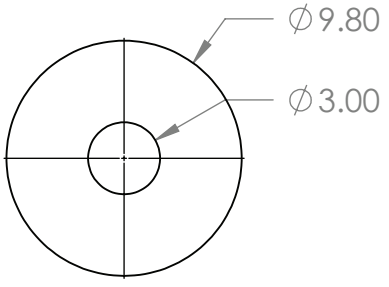


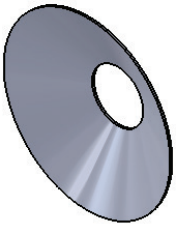


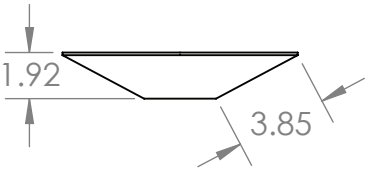




| | | |
|---|---|---|
| **TITLE:** Mold Band | **USED ON:** Briquette Mold | |
| **SCALE:** 1:8 | **MATERIAL:** 16 Gauge Galvanized Steel | |
| **DATE:** 4/1/17 | **FINISH:** Painted | Dimensions in inches |

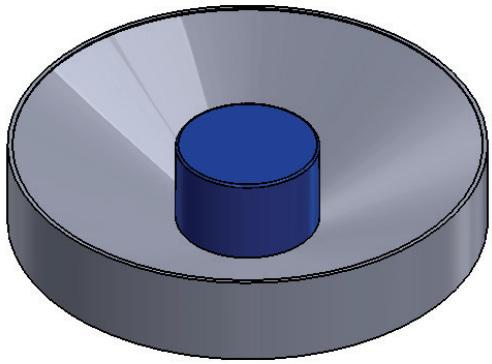


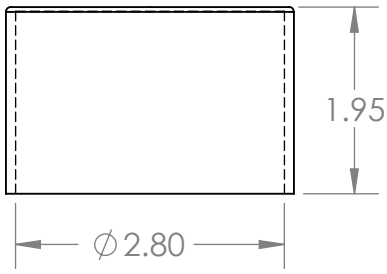


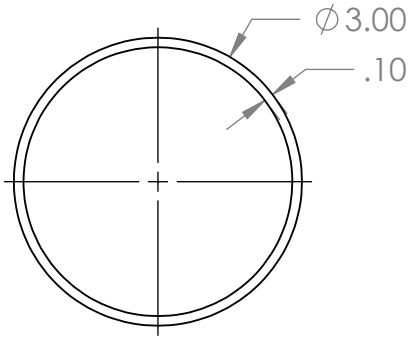



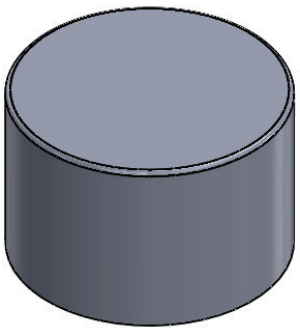



| | | |
|---|---|---|
| **TITLE:** Mold Dome | **USED ON:** Briquette Mold | |
| **SCALE:** 1:8 | **MATERIAL:** 16 Gauge Galvanized Steel | |
| **DATE:** 4/1/17 | **FINISH:** Painted | Dimensions in inches |





| | | |
|---|---|---|
| **TITLE:** Mold Cylinder | **USED ON:** Briquette Mold | |
| **SCALE:** 1:2 | **MATERIAL:** 16 Gauge Galvanized Steel | |
| **DATE:** 4/1/17 | **FINISH:** Painted | Dimensions in inches |

# 05

# Outcomes

# Analysis

**Conducted by Won Keun Oh*

## Radiation

The material of the prototype utilizes both stainless and galvanized steel. From the data sets, the temperature of the exterior wall reached 97.47c while water was boiling. **Boiling water only required 5.4% of total energy.**

The emissivity coefficient differs depending on the condition of the material. The average of duration of fire without adding more fuel is 1250.67 seconds.

**Emissivity** is the effectiveness of the surface of a material in emitting its energy as thermal radiation.

| Material | Emissivity Coefficient | Q(kJ) |
|---|---|---|
| Stainless Steel (Old) | .85 | 99.72406 |
| Stainless Steel (New) | .075 | 8.79918 |
| Galvanized Steel (Old) | .88 | 103.2437 |
| Galvanized Steel (New) | .23 | 26.98416 |

*Figure3. Emissivity Coefficient Table*

Due to less radiation heat loss over time in both old and new conditions, this result shows that **stainless steel would be preferred.**

## Recoverable Heat Energy in Wood

Species of wood significantly affects the **rate of burning, stored energy, and duration of the fire.** The sample set of firewood used for testing included a mixture of species.

**882.23g of mixed firewood was used to boil five liters** of water over an average of ~25 minutes, including bringing the water to a rolling boil for a minimum of two minutes, enough to kill all bacteria and viruses, cryptosporidium, and giardia (Boil Water Response).

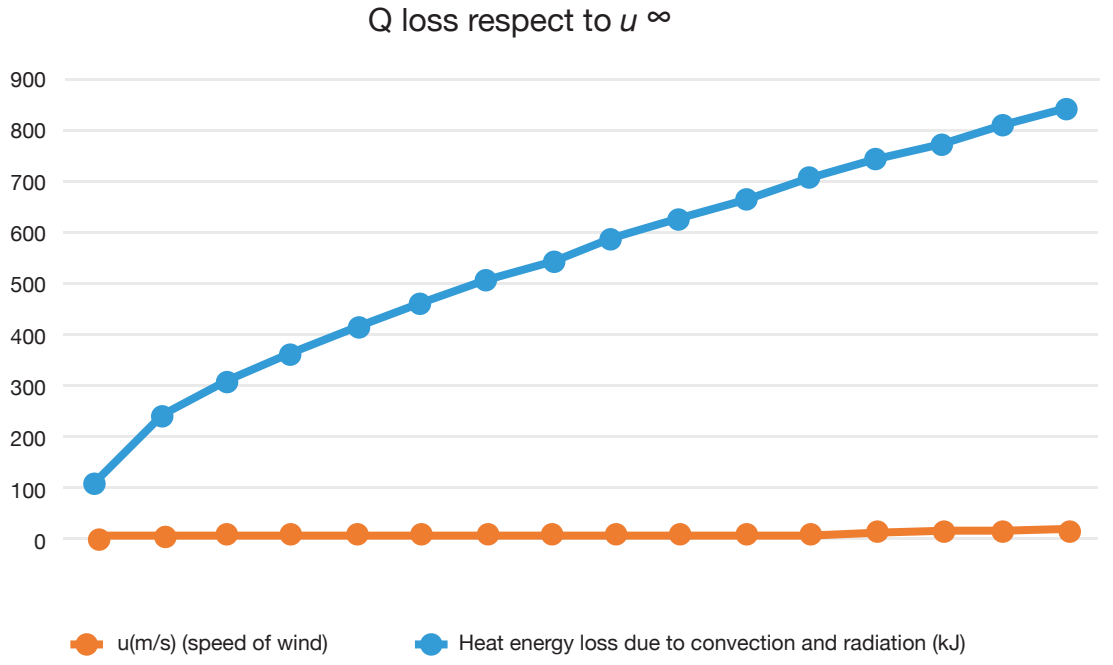
| Type of Firewood | kJ/kg |
|---|---|
| Bigleaf Maple | 19561.7528 (5) |
| Hickory | 21771.4633 (4) |
| Oregon Ash | 20003.6949 (5) |
| White Ash | 22399.4863 (2) |
| White Birch | 21724.9431 (2) |

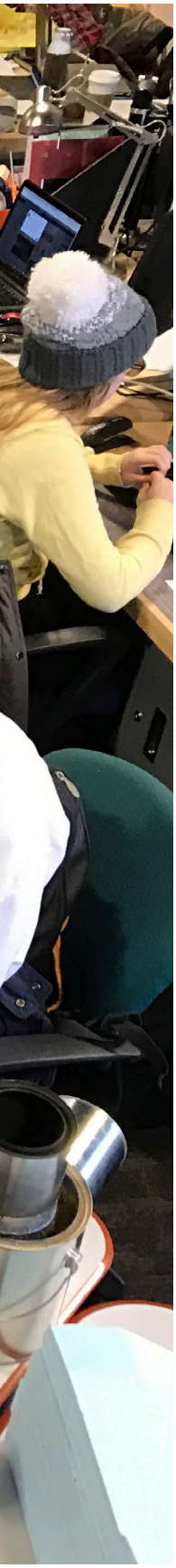
*Figure1. Recoverable Heat Energy in Wood*

## In Conclusion

Hera Stove proved to be a **beneficial and successful concept**, addressing multiple needs within our demographic, specifically cooking food, purifying water, and gathering fuel. However, **a significant amount of development could still be made** with a key focus on insulation and better-directed convective heat transfer.

**Improving insulation could reduce purification times, increase safety, and conserve fuel** by limiting energy loss and increasing efficiency.





# 06

# Acknowledgements

# Special Thanks

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Todd Kleinman
**Todd Kramer**
**Mike Leonard**
Kendyll McFarland
Mckenzie Miller
Amaury Nicasio
**Won Keun Oh**
**Mike Oldani**
Chris Pastore
Ariel Pechter
Dave Pechter
Mattea Pechter
Eric Schneider
Abhishek Shah
Shapeways
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